State of California

The Resources Agency

UFRMS DWR-1990
REFERENCE

Memorandum

Date : May 15, 1990

To : Clayton Magonigal, Chief
Water Operations Branch
Division of Operations and Maintenance

Wayne S. Gentry, Chief
Northern District

From : Department of Water Resources

Subject : Antelope Reservoir Sedimentation Survey

In September, 1989, the Northern District Geology Section conducted a bathymetric survey to determine the amount of sediment in Antelope Reservoir. This report discusses the results of that survey and how existing sediment infilling relates to reservoir capacity changes and watershed erosion rates.

Koll Buer, Senior Engineering Geologist, supervised the study. Jack McMillan, Associate Engineering Geologist, conducted the investigation and prepared the report. Shawn Pike and Julie Culp, Assistant Engineers, did field surveys and reduced the data. Shawn Thomas, Delineator, prepared the figures for the report. Anita Early and Roland Hall, Student Assistants, assisted in report preparation. John Brooks (USFS) and Dick Tagg (USGS) lent valuable technical support.

The study shows that gross sediment infilling has reduced the reservoir storage capacity by approximately two percent since 1964. Most of the sediment accumulated in a delta in the reservoir's northern arm and along the reservoir's thalweg in the southern arm. The sediment does not cause problems at the dam's outlet works. However, the infilling is limiting boat access in the stream channels near the Boulder Creek campground.

This study indicates that the annual watershed sediment contribution to the reservoir is roughly 40,000 tons/year. Sediment yield was determined for Lone Rock and Indian Creek in the northern arm and Antelope Creek in the Southern Arm. These tributaries yielded 880, 690, and 180 tons/sq mile/year respectively.

SURNAME	JRM 5/11/90	KR. Buer 5/16/90	for R&S 5/16/90	

ANTELOPE RESERVOIR

SEDIMENTATION SURVEY

Photo 1: This photo shows sediment infilling the stream channel near Lone Rock Creek campground September, 1989 with the water elevation at 4996 feet.

DEPARTMENT OF WATER RESOURCES
Northern District

March 1990

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INTRODUCTION

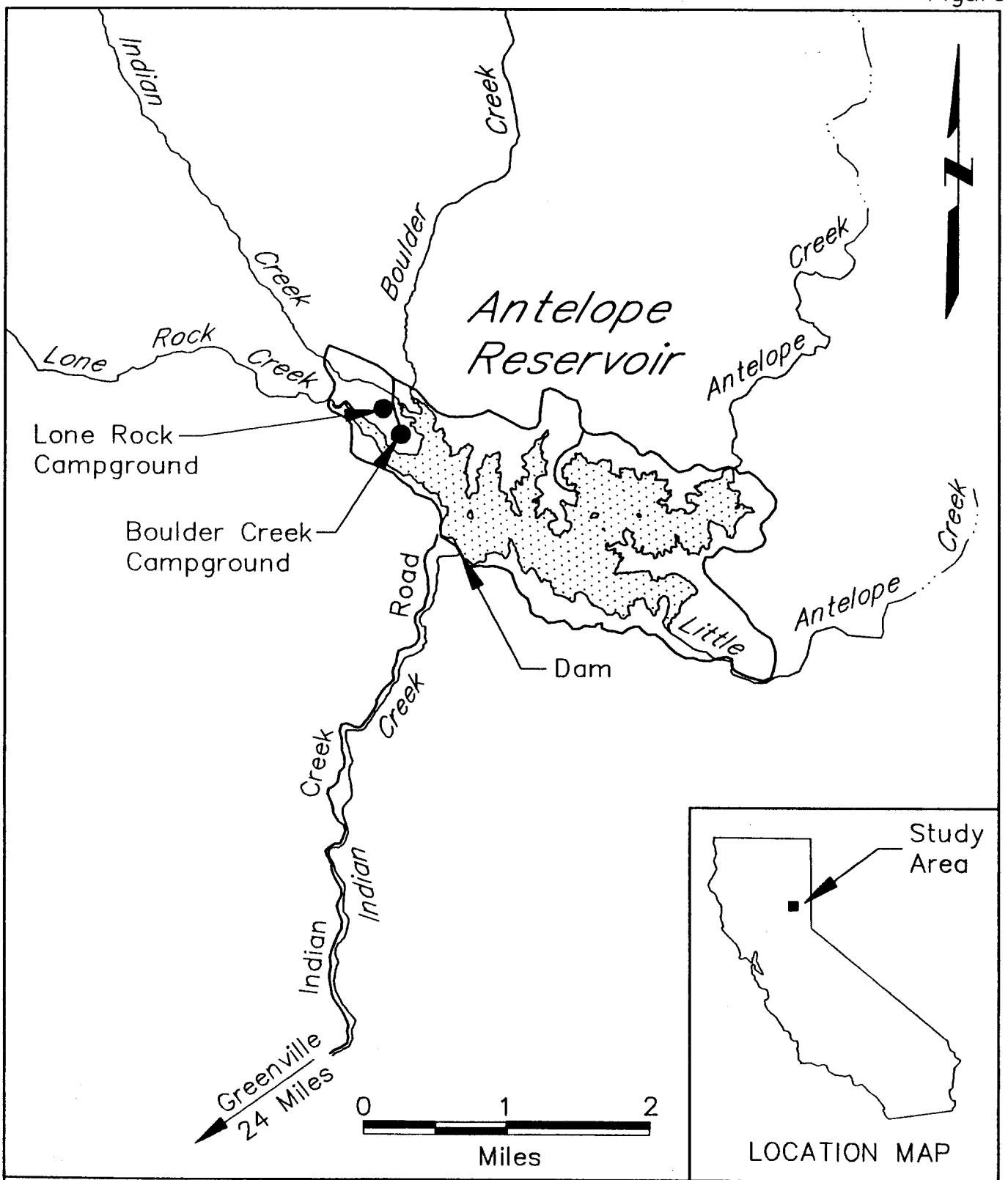
Location & General Features

Antelope Reservoir is about 24 miles east of Greenville in Plumas County (see Figure 1). The reservoir is in the upper reaches of Indian Creek and has two major arms. The northern arm is formed by the confluence of Indian Creek (which includes Boulder Creek) and Lone Rock Creek. The southern arm is formed by Antelope Creek, Little Antelope Creek and other smaller tributaries.

The majority of the reservoir watershed is underlain by Cretaceous (hornblende-biotite) granodiorite that forms the Diamond Mountains between Indian Valley and Honey Lake Basin. A large part (36%) of the Indian Creek drainage above the reservoir is underlain by Miocene rhyolite, dacite and andesite volcanic rocks (CDMG, 1989).

The Department of Water Resources (DWR) built Antelope Reservoir between 1957 and 1964 as part of the State Water Project to provide lake recreation and streamflow enhancement for Indian Creek. It has a surface area of 930 acres and a storage capacity of 22,570 ac-ft. The maximum pool elevation is 5,002 feet. Under present operating conditions, summer releases cause about 4 to 6 feet of annual change in the lake water surface elevation. Mean annual precipitation is 36 inches at Greenville, elevation 3,600 feet (USGS, 1975). Precipitation is greater over the watershed and falls mainly as snow during the winter at these elevations.

Figure 1



Location of Antelope Reservoir,
Plumas County, California

Purpose and Scope

In a recent erosion analysis, the USDA Soil Conservation Service (SCS) estimated that the watershed above Antelope Reservoir produces sediment at a rate of 146,800 tons/year or 2120 tons/sq mi/year (SCS, 1989). The Plumas Corporation and Plumas National Forest, through the local Coordinated Resource Management group (CRM), requested that DWR verify that estimate by conducting a reservoir bathymetric survey. The Division of Operations & Maintenance funded this investigation with $28,000.

Northern District personnel surveyed the reservoir using established range methods (USCE, 1961; SCS, 1983). Sediment "ranges" are fixed lines across the reservoir where initial elevation data can be compared to present elevations. Twenty-nine range lines were run and compared to the original topographic mapping. Limited bottom sampling to check sediment depths in the reservoir was done using a four-foot long brass sampler. No samples were taken for grain size or density analysis because of the lack of suitable sampling equipment.

This report documents the methodology and data used to estimate reservoir infilling since reservoir operation began in 1964. Conclusions on reservoir sedimentation and watershed sediment production rates are drawn from the survey data, a literature search and historic photo surveys. The bathymetric survey lines are monumented and can be used to monitor future reservoir sedimentation rates.

Previous Work

Most of the previous reservoir engineering data are from the 1957-64 construction investigation (DWR, 1964). That investigation included detailed foundation drilling and sampling at the dam site and two materials borrow sites inside the reservoir. The investigation also produced a 1:2400 scale reservoir topographic map. DWR compiled the map using 1963 aerial photos and surveyed control points. The 1963 map was used for the original bottom profiles along range lines in this investigation. In 1976, DWR re-photographed the reservoir during a drought period with the water level at about elevation 4,940 feet.

Since constructing the dam, DWR has monitored the fishery and recreation use at the reservoir and along Indian Creek and published these data in a number of DWR technical reports (DWR, 1981). The U. S. Forest Service has inventoried the geology and erosion processes in the watershed above Antelope Reservoir and has much of that information on file in Quincy. The Soil Conservation Service, in cooperation with the Plumas Coordinated Resource Management Group (CRMP), recently completed an Erosion Inventory (SCS, 1989) using detailed road and stream surveys and the Universal Soil Loss Equation.

Other important information includes a recently compiled geologic map (scale 1:100,000) by the California Division of Mines and Geology (CDMG, 1989).

SUMMARY AND CONCLUSIONS

Sediment in Antelope Reservoir has decreased its storage capacity approximately two percent since 1964. Because of where the sediment accumulates, it does not present operational problems to the reservoir's outlet structure. However, sediment infilling is limiting boat access and recreation at the Boulder Creek campground.

Volume of sediment in the reservoir is approximately 830,000 cubic yards. The sediment has accumulated in a delta deposit in the reservoir's northern arm near the confluence of Indian, Boulder, and Lone Rock Creeks and along the thalweg of the southern arm.

1) The northern arm delta is approximately 100 acres in extent and averages 4.5 feet thick. Stream channels have filled in 5 to 8 feet locally with a maximum sediment thickness of 15 feet.

2) The southern arm sediments have accumulated along the lower channel areas of the reservoir. This accumulation is approximately 25 acres in extent and averages less that one foot thick.

A gross sedimentation rate estimate over the 25-year reservoir life suggests that Lone Rock Creek, Indian Creek, and Antelope Creek yield 880, 690, and 180 tons/sq mile/year, respectively, to the reservoir. The remaining southern arm tributaries yield roughly 140 tons/sq mile/year to the reservoir.

RECOMMENDATIONS

A sediment coring and sampling program should be conducted to examine the annual changes in the sediment accumulation in the northern delta. This would refine the estimated annual rate of sedimentation and show any changes in the rate over the last 25 years.

Additional survey lines should be established along the Indian Creek, Boulder Creek, and Lone Rock Creek channels for input into a sediment transport computer model (Fluvial 12). These data would help predict future channel changes near the Boulder Creek campground.

Hydrologic data and suspended sediment samples should be collected to quantify stream sediment load and reservoir trap efficiency.

The results of this bathymetric survey should be formally integrated with the U. S. Forest Service and Soil Conservation Service monitoring and erosion inventory programs.

METHODOLOGY

Field Methods

Between August 28 and September 29, 1989, the Northern District surveyed twenty-five bathymetric range lines[1]/ at Antelope Reservoir using a boat-mounted, continuous depth recorder and four land lines using surveying instruments. The end points of each range were surveyed and monumented (see survey notes in Appendix A). Survey traverse lines were tied to permanent property bench marks set by the Division of Operations and Maintenance.

Twenty-two ranges were run between August 28 and September 1. Three additional ranges were run by boat on September 28 & 29. In addition, four land lines were surveyed to provide more data in the northern arm of the reservoir. Sediment deposits were examined in the field using a soil auger and bank exposures in the delta areas.

The water surface elevation was 4997.8 feet during the first survey and 4996.3 feet during the second. There was little wind and no current affecting either of the measurements.

Precision

The bottom profiles along the range lines do not precisely match the cross-sections plotted from the topographic map because of minor velocity and

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1/ Note: The term "range" or "range line" refers to a surveyed bottom profile in the reservoir. The term "cross-section" or "profile" refers to the graphed range data presented in the figures of this report.

course adjustments. This is particularly noticeable near the ends of the range lines where the boat speed was reduced near the shore. As a result, the ends of the range lines are less accurate than the middle of the range lines. Minor adjustments have been made to the cross-sections to achieve a "best fit".

Data Reduction

The surveyed range lines were plotted on a 1:2400 scale topographic map that DWR compiled during dam construction for area-capacity analysis. This map shows the pre-reservoir topography accurately at a five-foot contour interval except in one area near the dam that was underwater during part of the construction period. The 1989 surveyed range lines were then compared to the 1964 ground surface profiles using SuperCalc and AutoCad computer programs. The points shown on each range cross-section are surveyed land shots, digitized points from the sonar strip chart records, and elevation contours from the 1964 map. The digitized points were chosen at significant slope breaks; therefore, fewer points on the 1989 profiles do not indicate less accuracy.

The amount of sediment in the reservoir was estimated by: 1) comparing the 1964 and 1989 survey data, 2) determining the amount of deposition at each range line, and 3) multiplying the area of sediment by the reservoir length that each range line represents.

In the northern arm where a delta has formed, this estimate was checked by contouring the area of sediment accumulation and calculating a volume based on the planimetered areas and depths from the survey data. The area of sediment accumulation was estimated by comparing 1963 and 1976 aerial photographs. These photos show the areas of major sedimentation ten years after reservoir filling. The planimeter method and cross-sectional area calculations agree within 15 percent.

The volume of sediment accumulated in the southern arm of the reservoir was found using the same method as above.

RESULTS

The results of this survey are discussed under three headings: Reservoir Changes, Northern Arm; Reservoir Changes, Southern Arm; and Watershed Sediment Yield Rates.

Reservoir Changes, Northern Arm

Range Analysis

Figure 2 shows all the range lines that were surveyed during this investigation and the locations of bottom samples and bank cut exposures. The range lines run in the northern arm show sediment infilling that averages 4.5 feet thick with a maximum thickness of 14 feet. The cross-sections are grouped into Lone Rock Creek and Indian Creek for ease of discussion even though the streams contribute to the same delta deposit.

Lone Rock Creek. Four range lines were run on Lone Rock Creek (see Figures 3 & 4). Profiles L1 to L3 were made by land survey and the 1989 data are accurate to within +/- 0.1 foot. The apparent erosion along the west ends of these lines results from the greater precision of the 1989 profile than the 5-foot contour interval accuracy of the 1964 profile. Along line L2 there may be an actual change since 1964, or it may have been caused when the rod person swung off line to avoid the marshy area along a secondary channel. Line L4 (Figure 4) was run from the boat. The 1989 profile is precise to within +/- 1 foot.

Figure 2

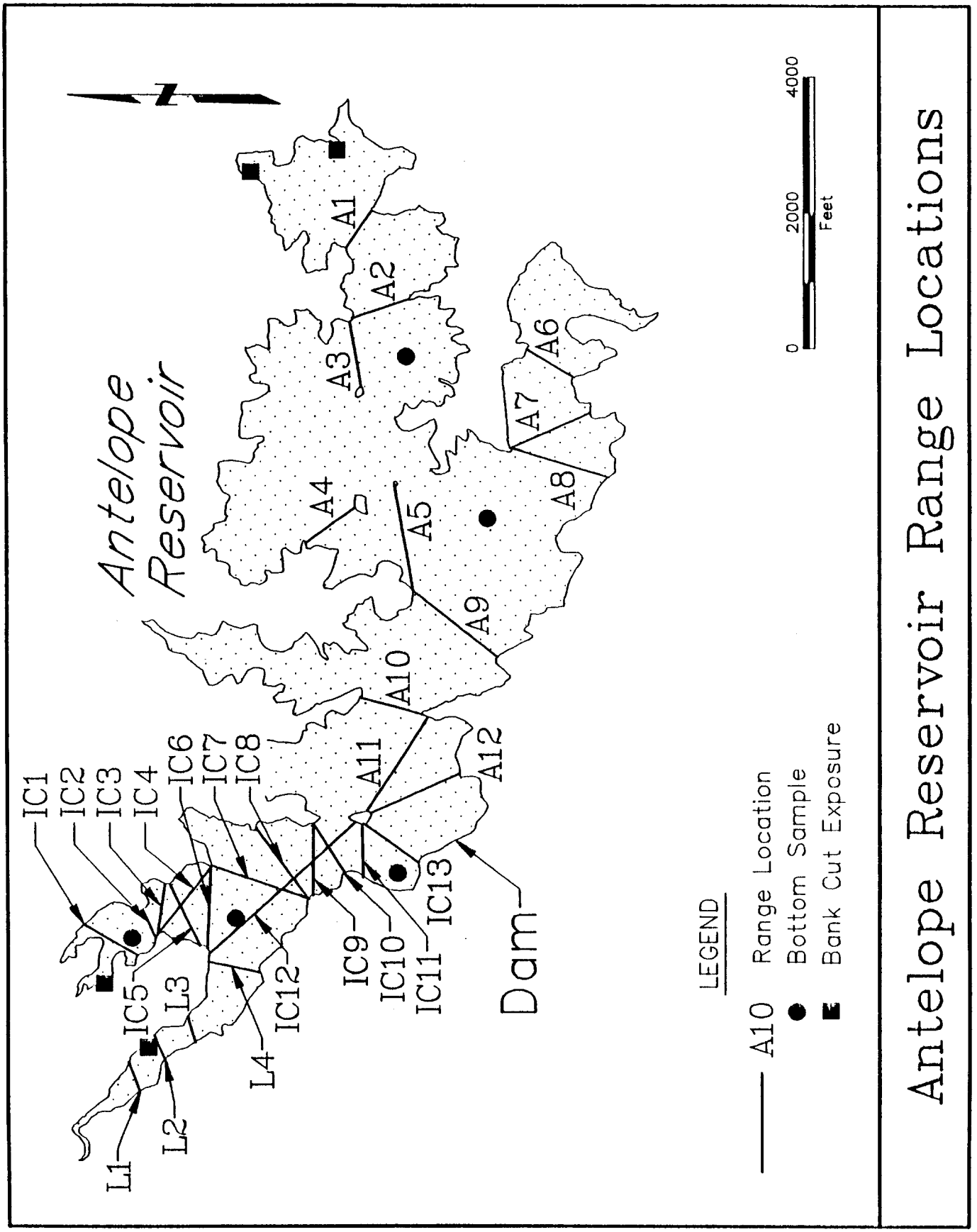
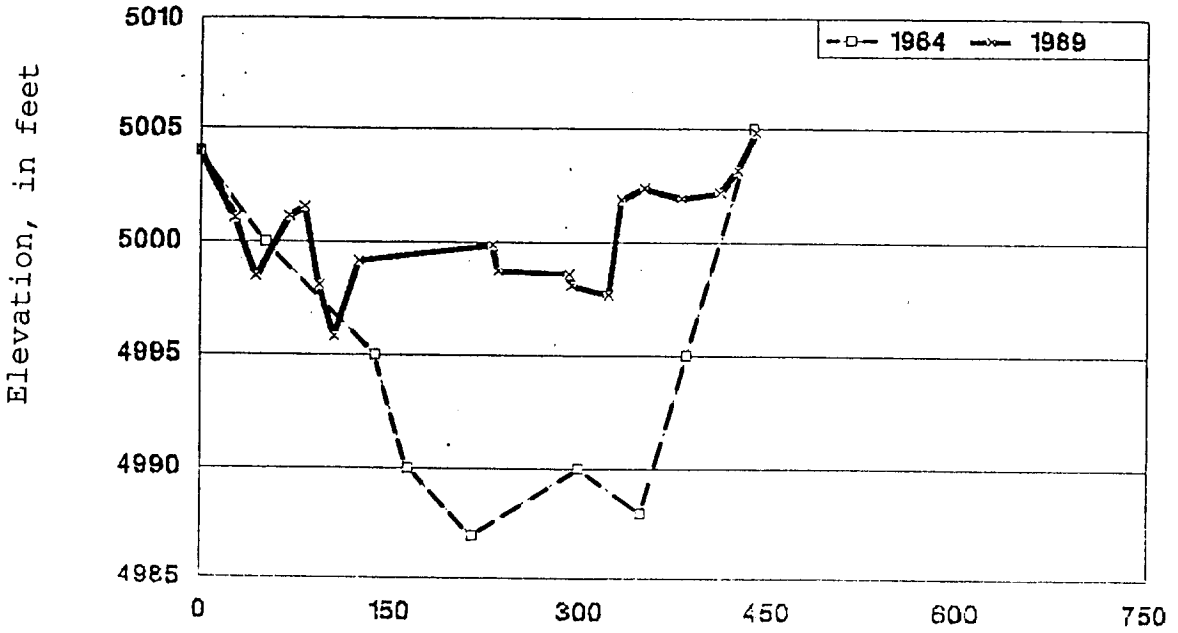
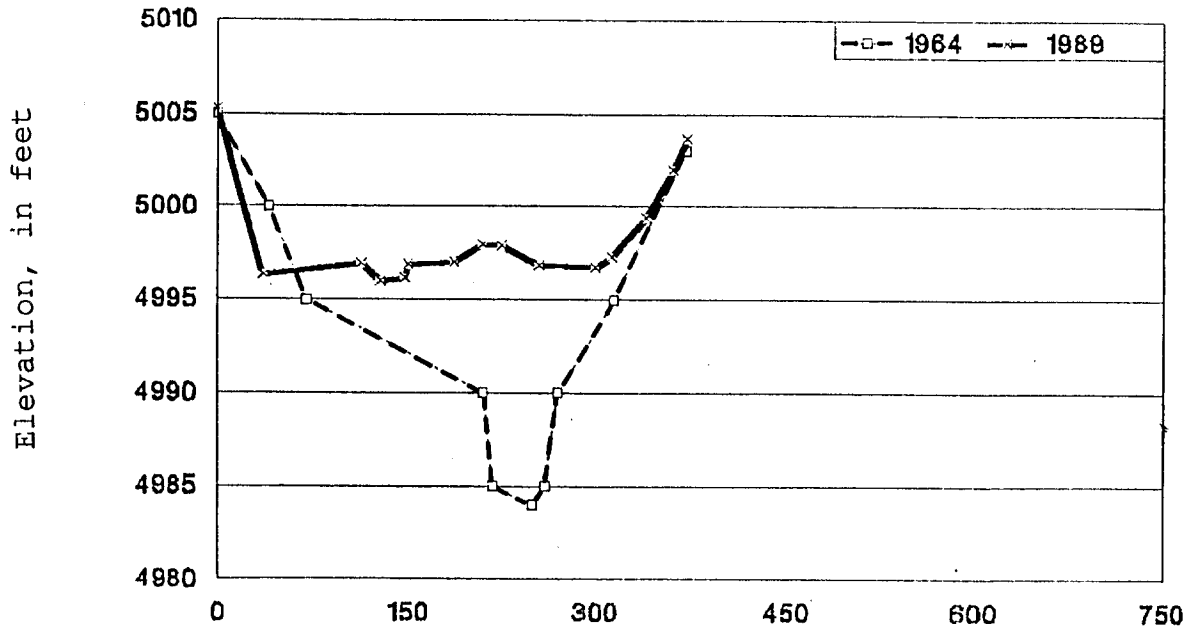

Antelope Reservoir Range Locations
Antelope Reservoir
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
IC1
IC2
IC3
IC4
IC5
IC6
IC7
IC8
IC9
IC10
IC11
IC12
IC13
L1
L2
L3
L4
Dam
0
2000
4000
Feet
LEGEND
A10 Range Location
Bottom Sample
Bank Cut Exposure

Figure 3

L1-LINE
Southwest----->Northeast



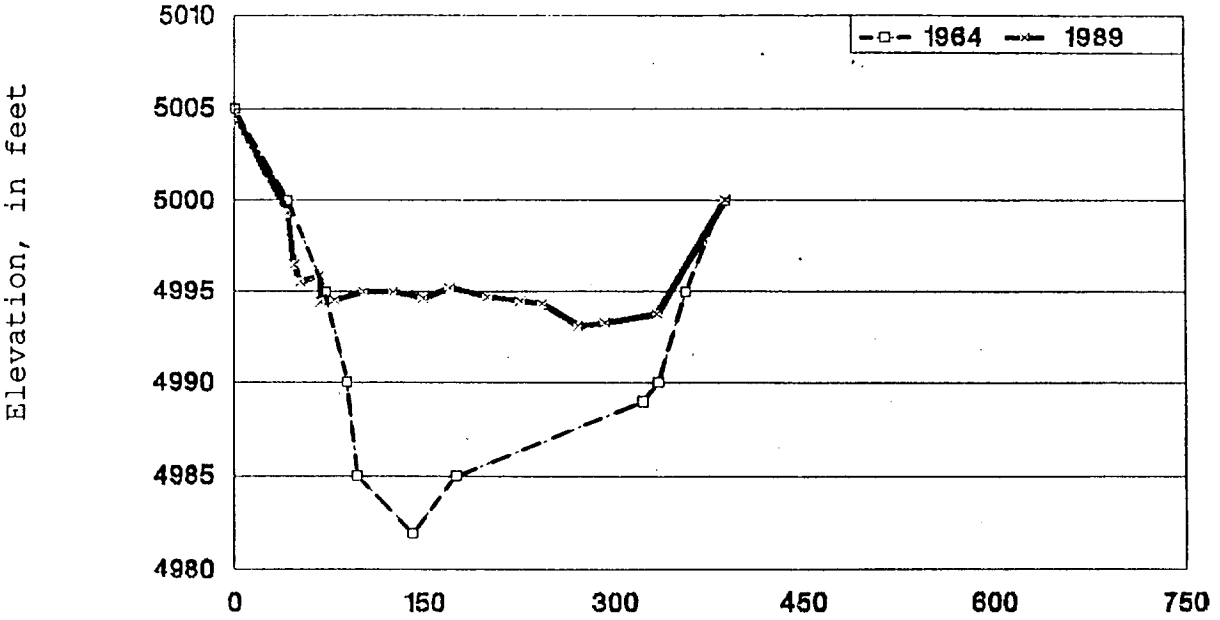
L2-LINE
West----->East



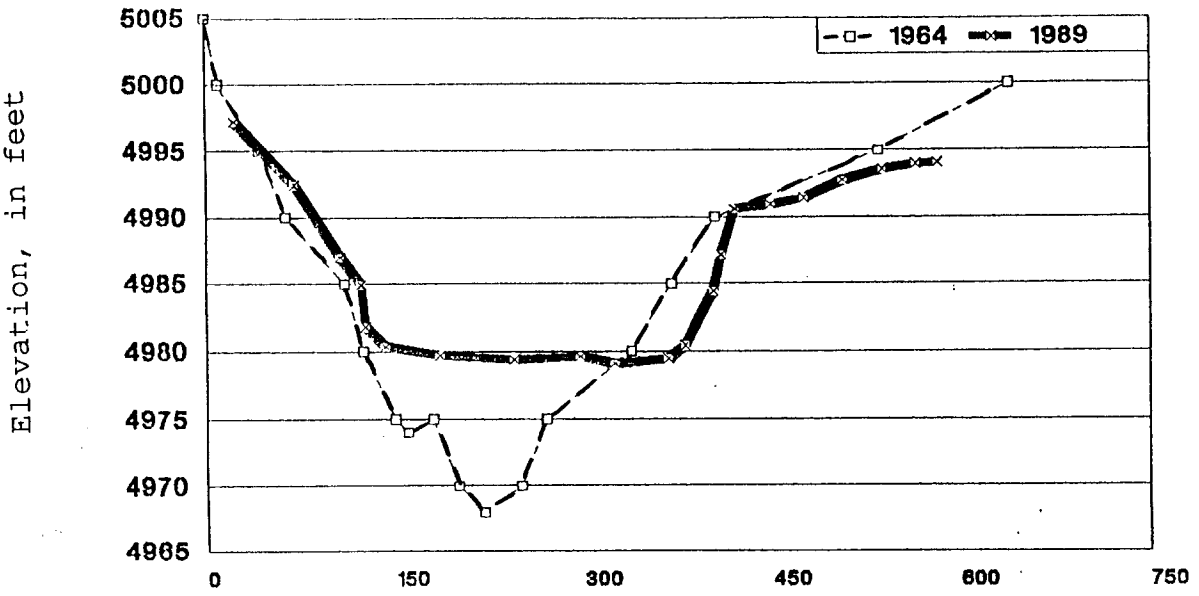
Distance along range lines, in feet

Figure 4

L3-LINE
West----->East



L4-LINE
South----->North



Distance along range lines, in feet

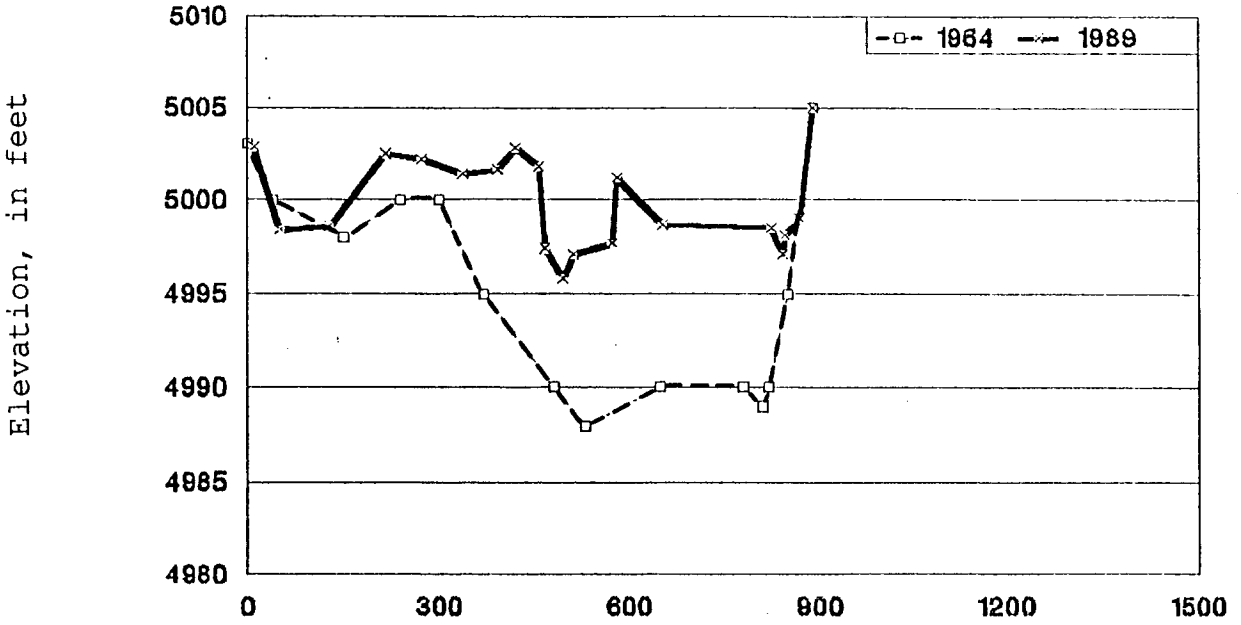
The apparent erosion on the northern end of range line L4 results from poor topographic control in one area of the original map. The 1963 aerial photographs show an eroded bank at this location that was not contoured on the 1964 topographic map. These cross-sections show that there is 0 to 14 feet of reservoir deposition in Lone Rock Creek along its full length.

Indian Creek. Thirteen ranges were run on Indian Creek (see Figure 2, page 11). Profiles IC1 & IC2 (Figure 5) were made by land survey and the 1989 data are precise to within +/- 0.1 foot. The remaining profiles were run from the boat and are accurate to within +/- 1 foot.

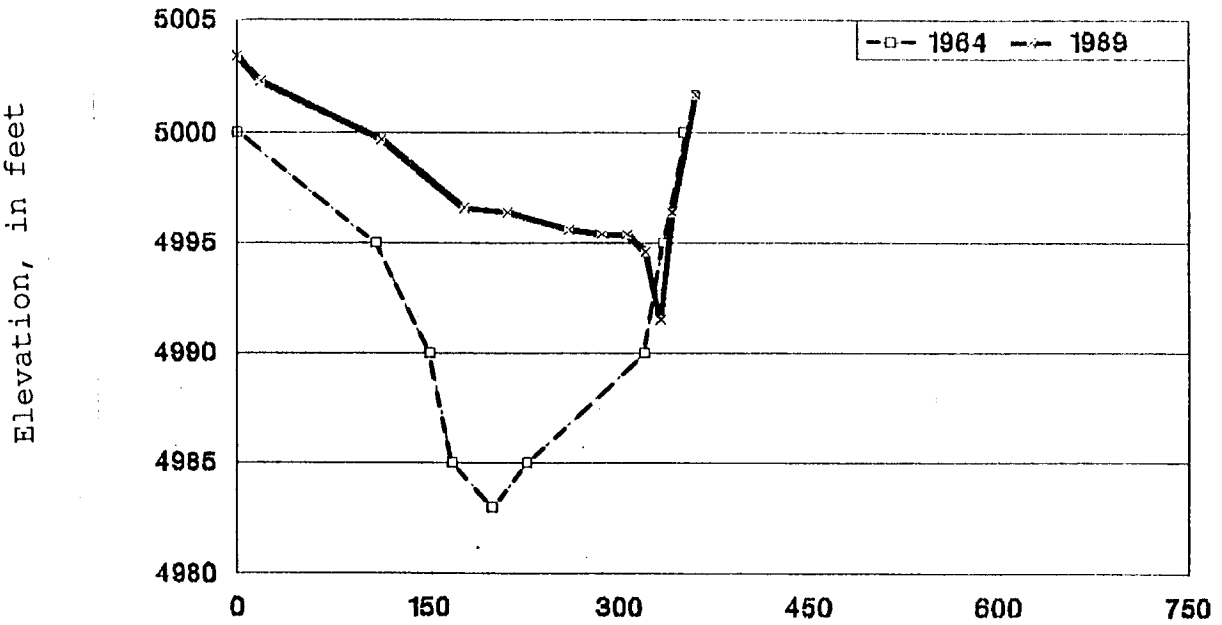
The 1964 to 1989 range comparisons of IC1 through IC10 (see Figures 5 to 9) show that the sediment deposit in Indian Creek ranges from 0 to 15 feet thick. At the lower end of Indian Creek near Dedication Island, ranges IC11 and IC13 (Figure 10 & 11) show no significant sediment deposition. The longitudinal profile shown in IC12 (Figure 10) documents this "thinning effect" down the stream channel and into the reservoir. Where range line IC12 crosses the old stream channel, it shows sediment deposition. Where the range crosses ridges, it is clean. The thickness of sediment in the channel decreases progressively from the stream inlets to Dedication Island. The southeast end of the range where it crosses the channel shows no significant deposition.

Figure 5

IC1-LINE
Southwest----->Northeast



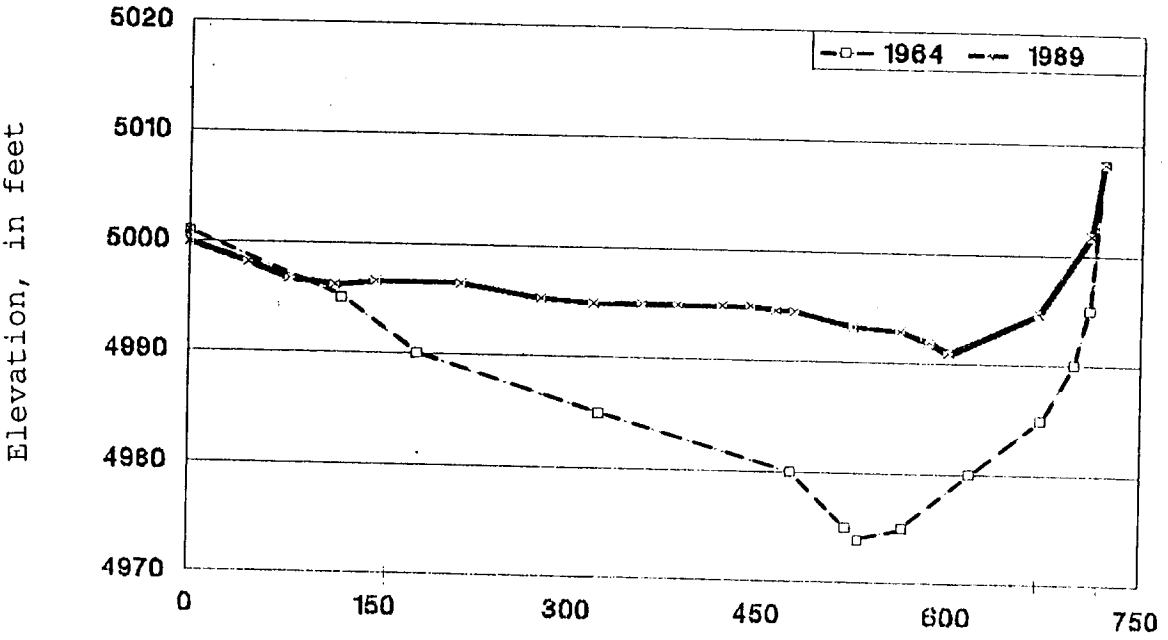
IC2-Line
West----->East



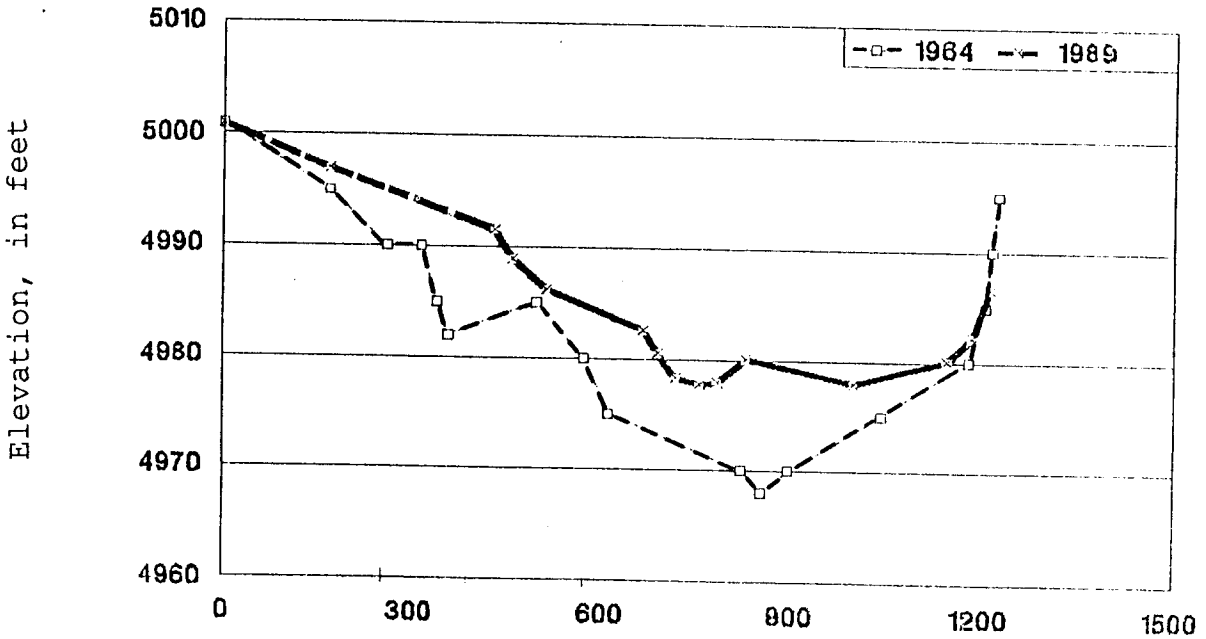
Distance along range lines, in feet

IC3-LINE
West----->East

Figure 6



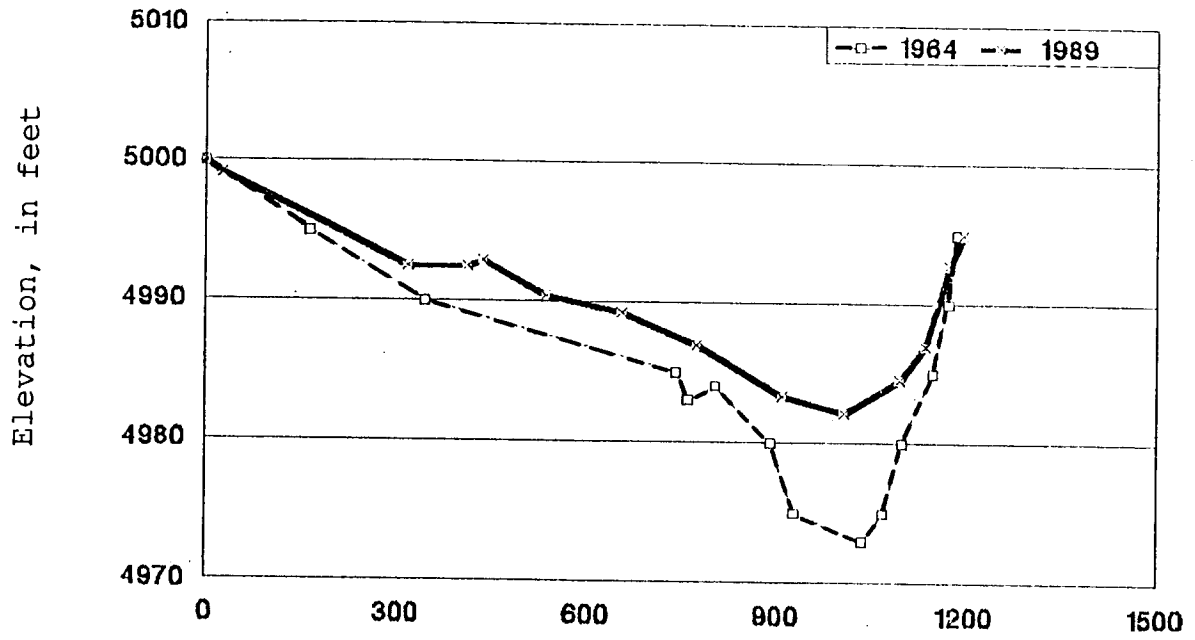
IC4-Line
Northwest----->Southeast



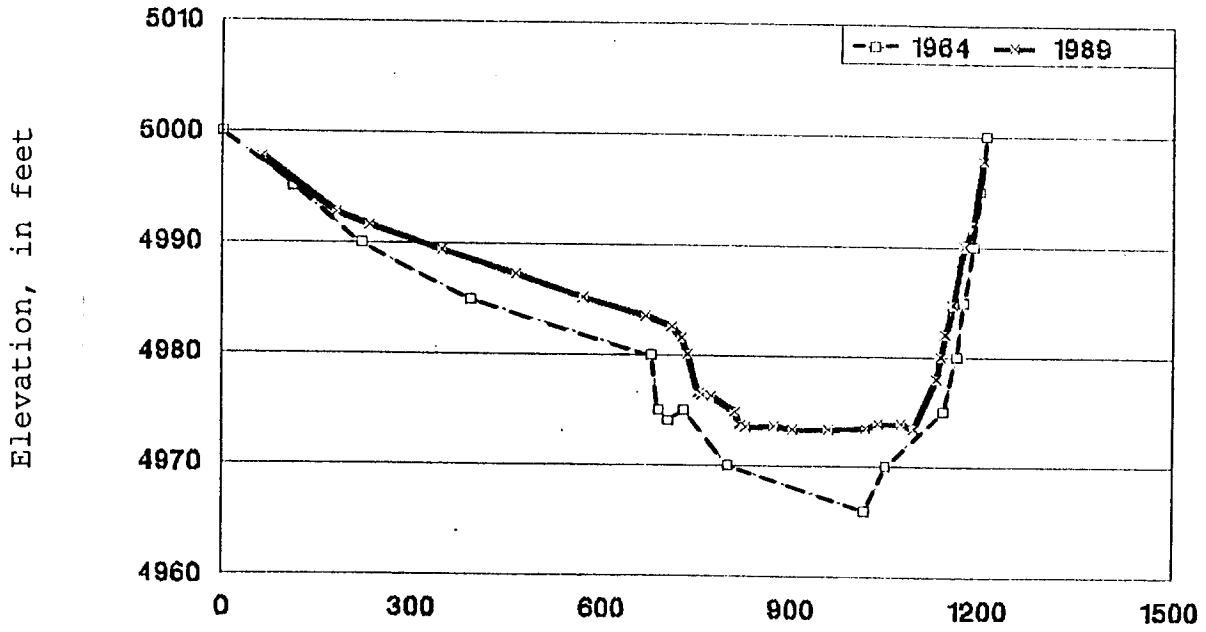
Distance along range lines, in feet

IC5-LINE
Southwest----->Northeast

Figure 7



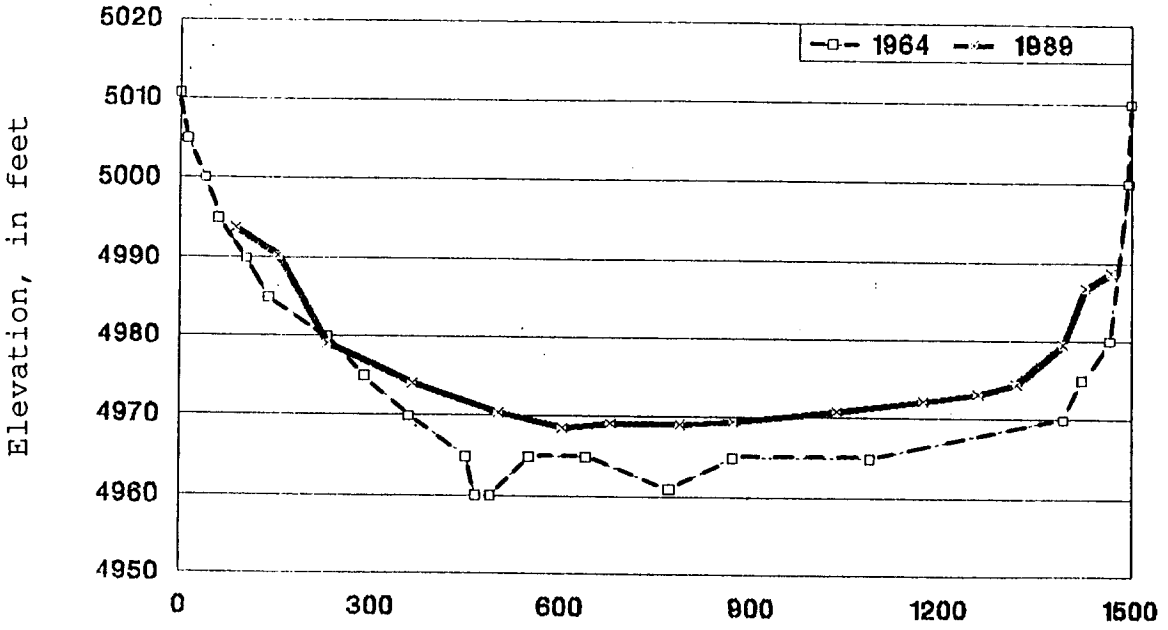
IC6-LINE
West----->East



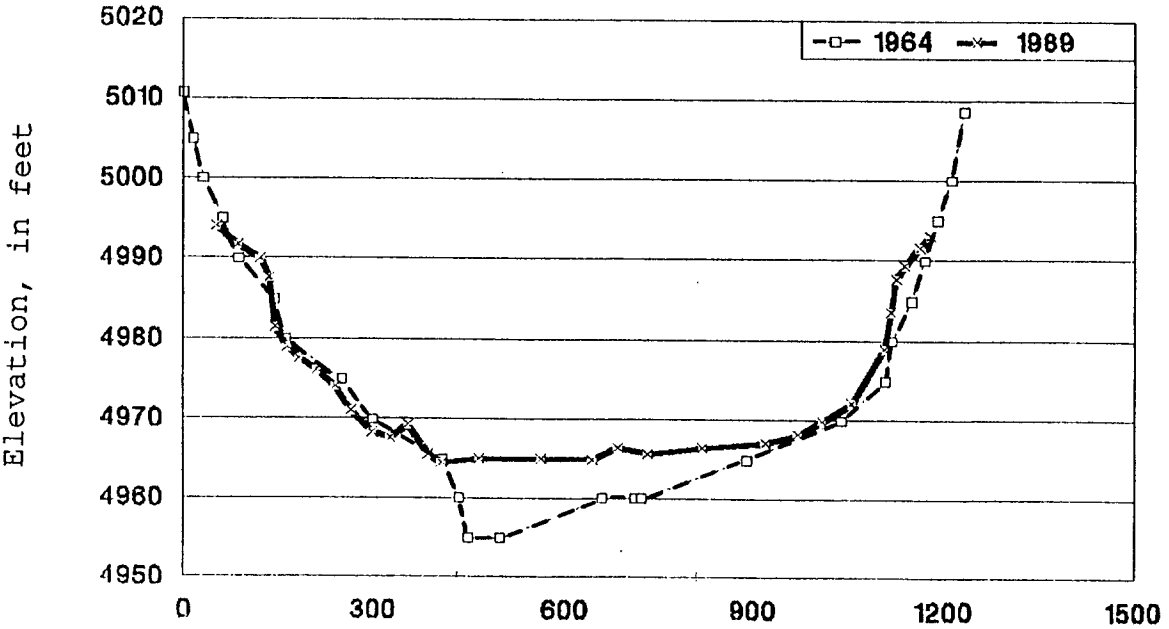
Distance along range lines, in feet

Figure 8

IC7-LINE
South----->North



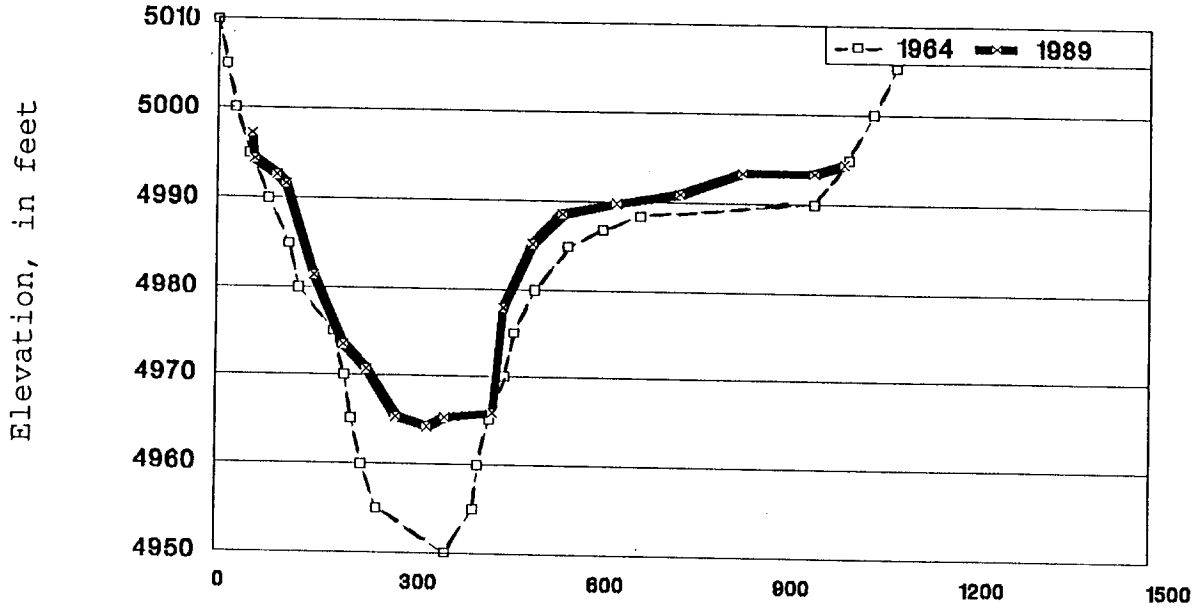
IC8-LINE
Southwest----->Northeast



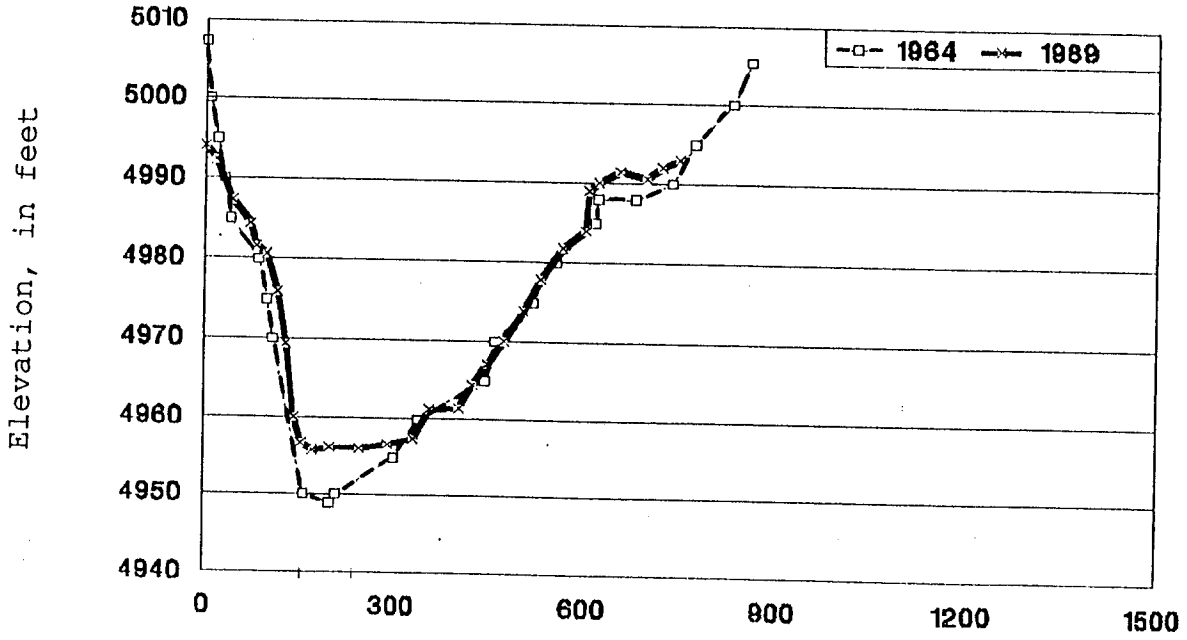
Distance along range lines, in feet

Figure 9

IC9-LINE
West----->East



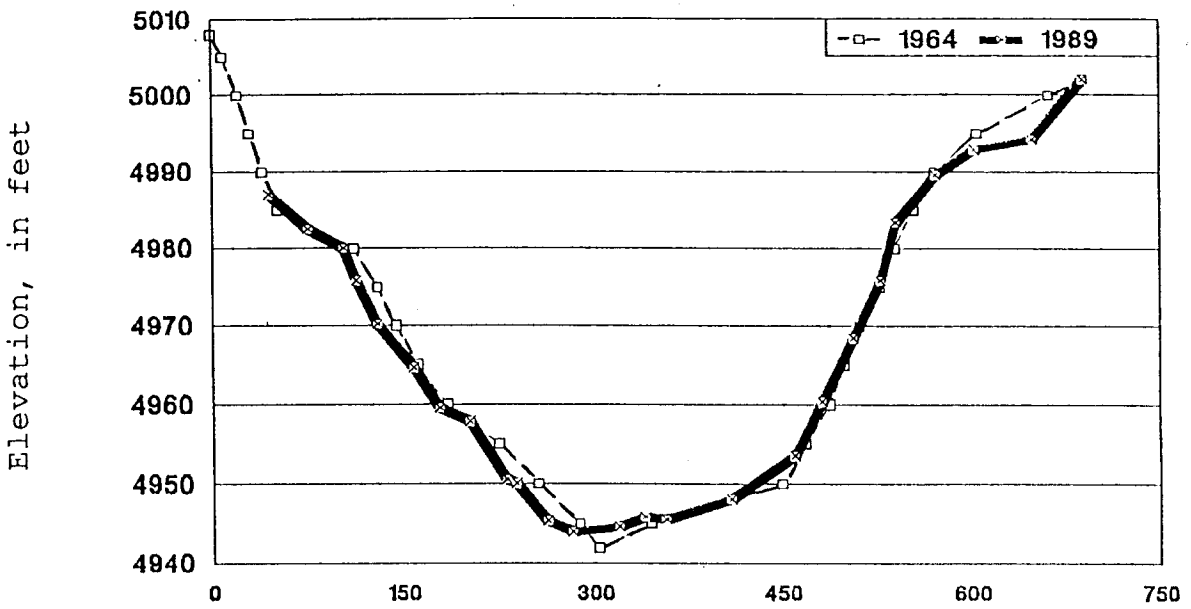
IC10-LINE
Southwest----->Northeast



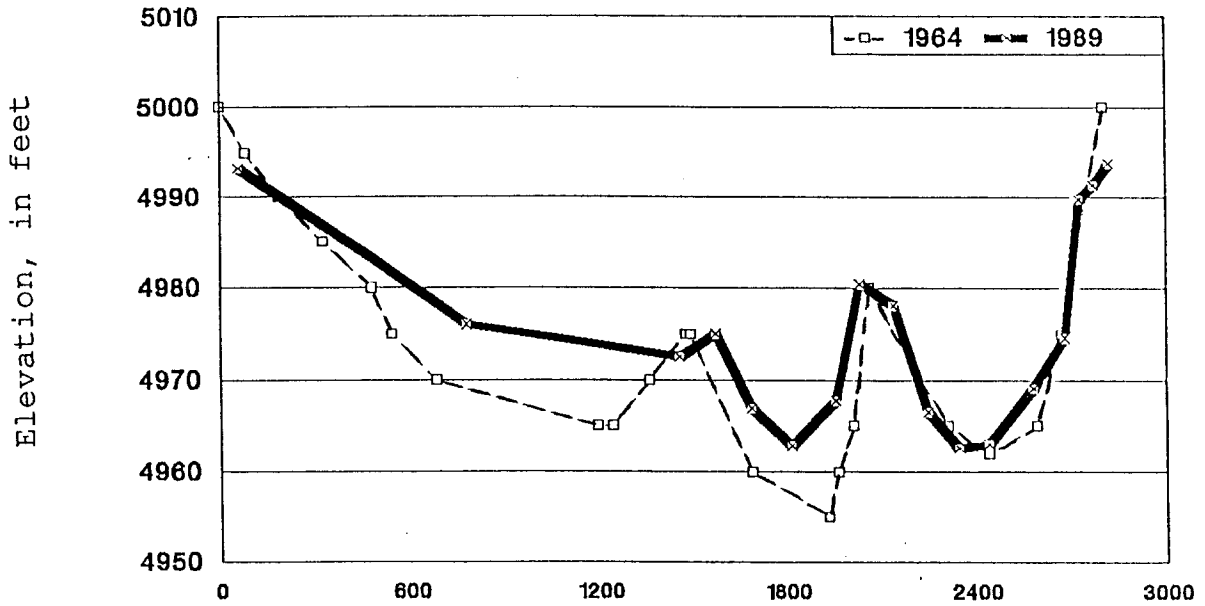
Distance along range lines, in feet

Figure 10

IC11-LINE
West----->East



IC12-LINE
Northwest----->Southeast



Distance along range lines, in feet

Figure 11

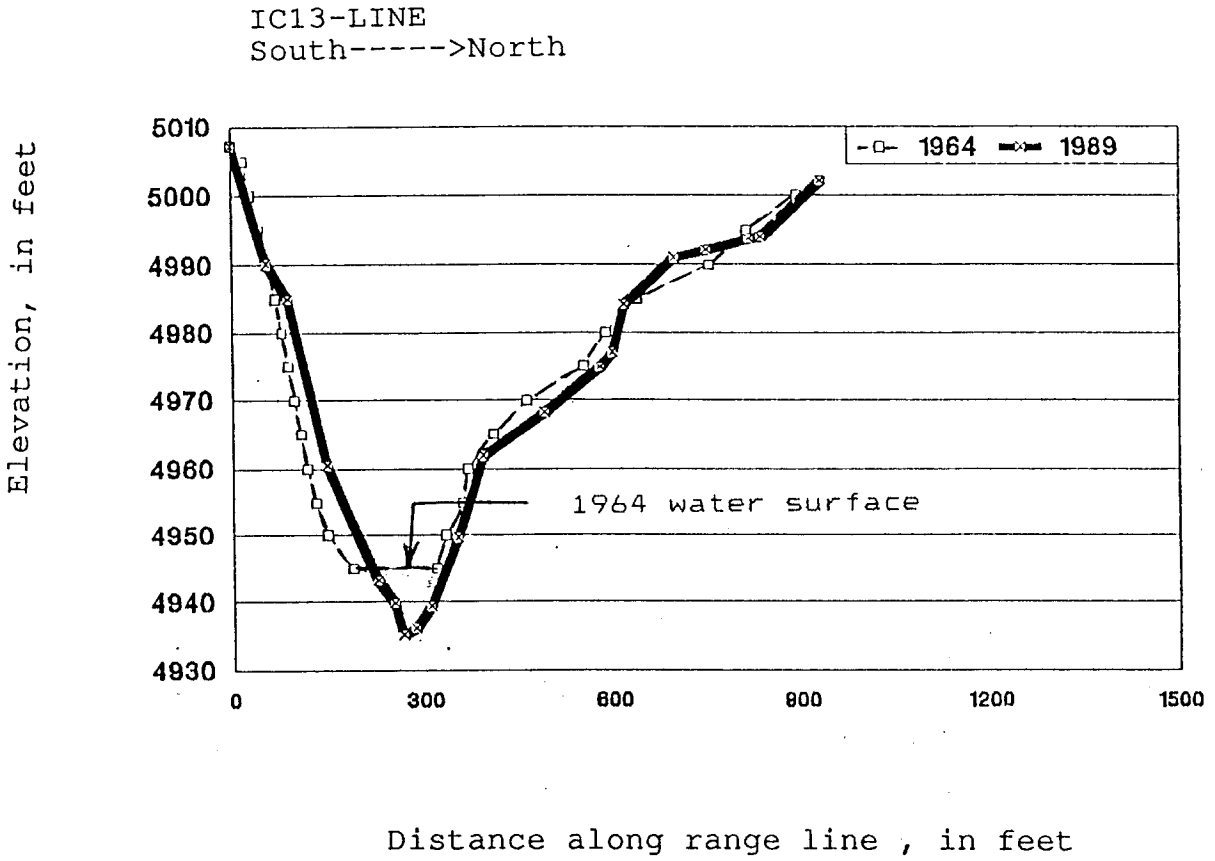

IC13-LINE
South----->North
Elevation, in feet
5010
5000
4990
4980
4970
4960
4950
4940
4930
0
300
600
900
1200
1500
1964
1989
1964 water surface
Distance along range line , in feet

Photo Analysis

Lone Rock, Indian, and Boulder Creeks enter the northern arm of the reservoir northwest of Dedication Island. Photo 2 shows the northern arm in 1977 with the reservoir water surface elevation at 4,955 feet (Dedication Island is on the right edge of the photo). The reservoir side slopes are clean, lacking any indication of sediment deposition above 4,955 feet elevation. The dark-colored sediments in the background of the photo are delta deposits near the mouth of Indian Creek.

Photo 2: Northern arm of Reservoir in 1977 showing clean side slopes near Dedication Island and channel sediments upstream near the mouth of Indian Creek.

Photo 3 shows the upper end of Lone Rock Creek where it enters the reservoir. The water surface elevation in this 1989 photograph is 4,998 feet. The channel area and part of the grass are covered by water when the reservoir is at its maximum pool elevation of 5,002 feet. Vertical photographs taken in 1976 by DWR show that the main channel along the thalweg was filled with sediment by 1976. Sedimentation since then has completely filled the active channel and deposited material on the bank areas that flank the channel. Indian and Boulder Creeks show similar infilling adjacent to the Boulder Creek Campground facilities.

The total area of sediment accumulation near the confluence of Lone Rock Creek, Indian Creek and Boulder Creek is approximately 100 acres. The mean depth of this sediment is 4.5 feet and ranges from 0 to 14 feet locally.

Photo 3: Lone Rock Creek showing sediment deposits in the active stream channel and on overbank areas in 1989. Water elevation is 4,998 feet.

Reservoir Changes, Southern Arm

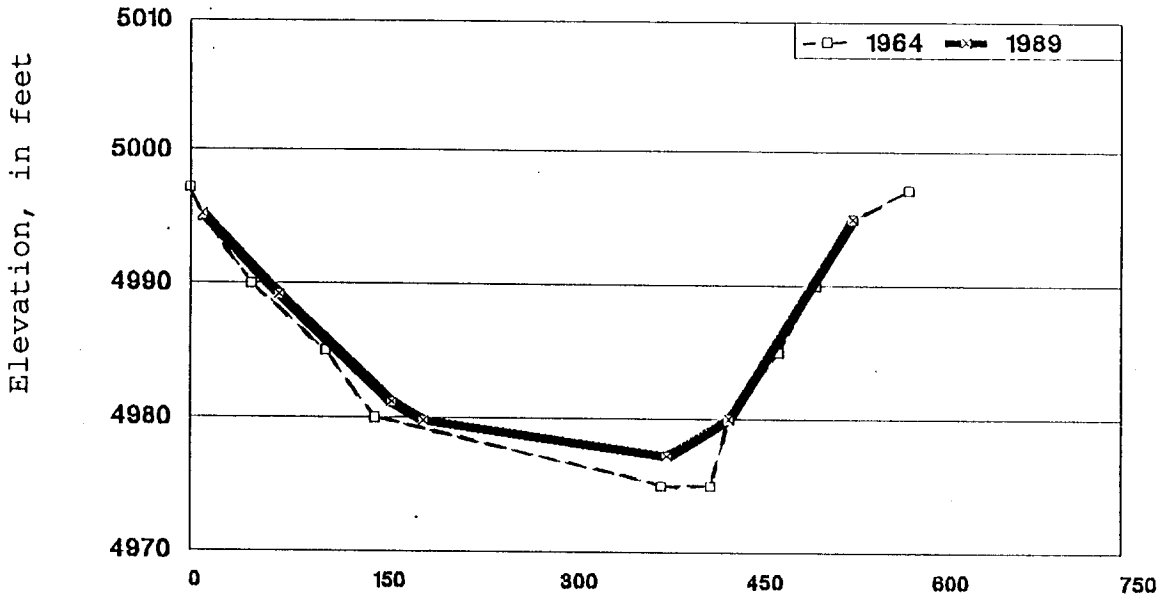
Range Analysis

Twelve ranges were run in the southern arm of the reservoir east of the dam (see Figure 2, page 11). A1 through A4 show between 1 and 3 feet of sediment deposition restricted to a narrow area along the reservoir's thalweg (see Figure 12 and Appendix B). Most of the ranges were run for long distances across open water and do not fit the original topography very well. However, all the range data suggests that there is less sedimentation in the southern arm than in the northern arm.

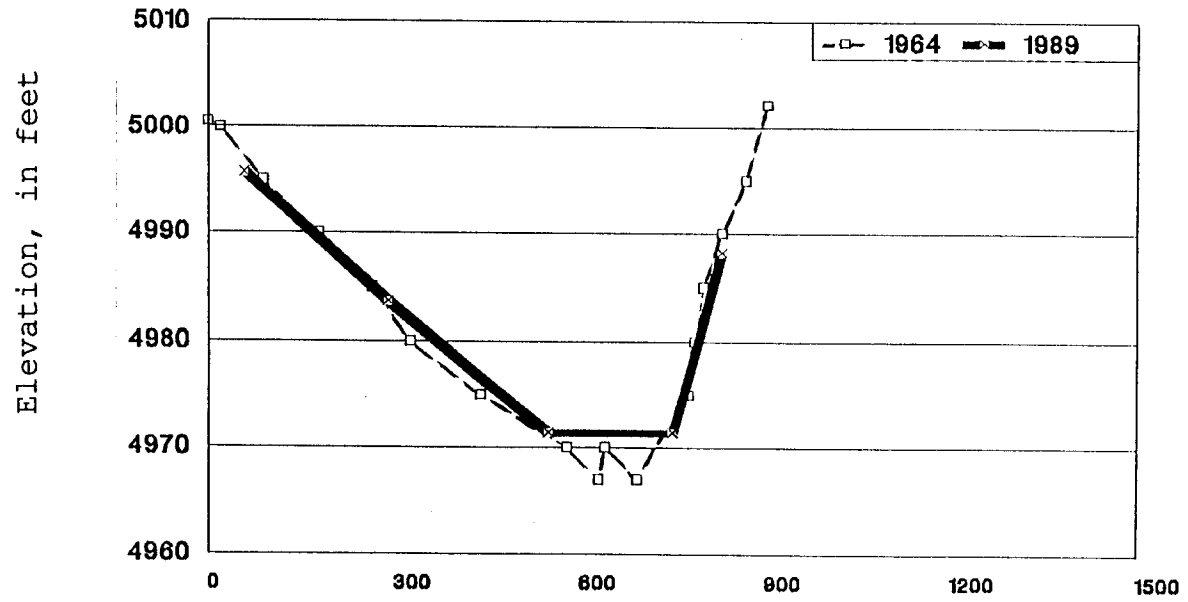
Three range lines near the dam, A11, A12, and A13 (see Appendix B) show 1989 thalweg elevations that are lower than the 1964 elevations. These resulted either from poor topographic control on the original channel survey or from construction modifications that are not recorded on the 1964 topographic map. The map did not have contours below the 4,945 feet elevation in this area. The vertical accuracy of the range line survey in the southern arm is probably +/- 1 foot.

Figure 12

A1-LINE
Northwest----->Southeast



A2-LINE
North----->South



Distance along range lines, in feet

Photos and Bottom Sampling

Photo 4 is a 1977 aerial oblique view[2] of the reservoir with the reservoir elevation near 4,970 feet during the 1976-77 drought. There is a delta at the mouth of Antelope Creek (upper right corner-Photo 4) in the area where range lines A1 & A2 indicate an average 1.5 feet of deposition.

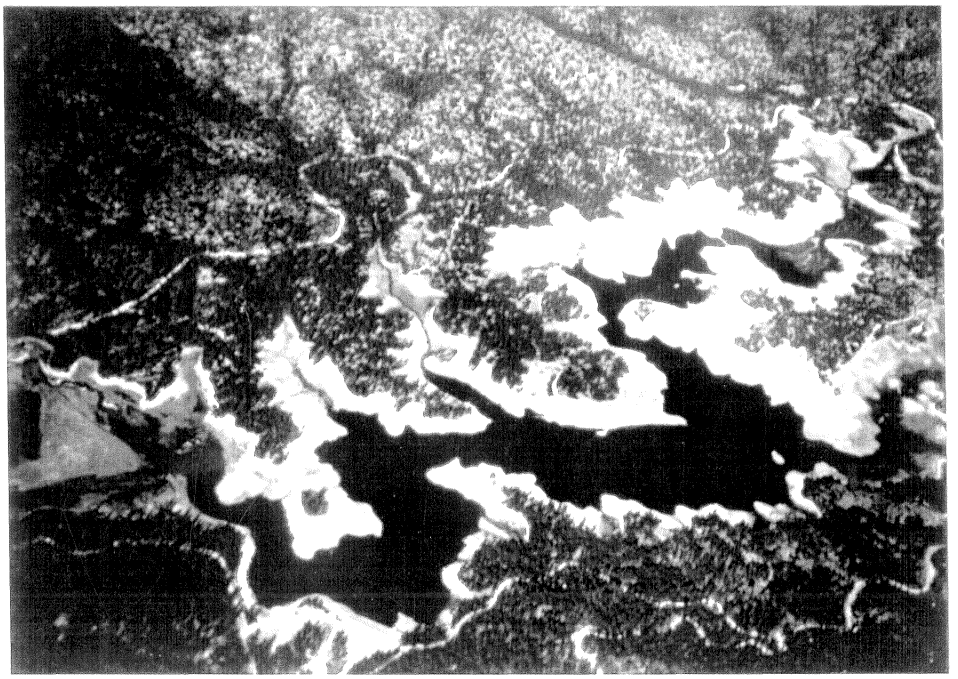


Photo 4: Aerial view of Antelope Reservoir, 1977. Note the delta in the upper right corner of the photo at the mouth of Antelope Creek.

Soil auger holes near the mouth of Antelope Creek show a thin vegetation cover over weathered granite bedrock. Limited bottom sampling in this area yielded either in-place, decomposed granitic sand or what appeared to be original soil material with roots. The photos, bottom sampling, and range

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2/ This photo is not part of the 1976 vertical photos that were used for sediment analysis.

data suggest that the sediment deposition in the southern arm is confined to the mouth of Antelope Creek and the reservoir thalweg.

Watershed Sediment Yield Rates

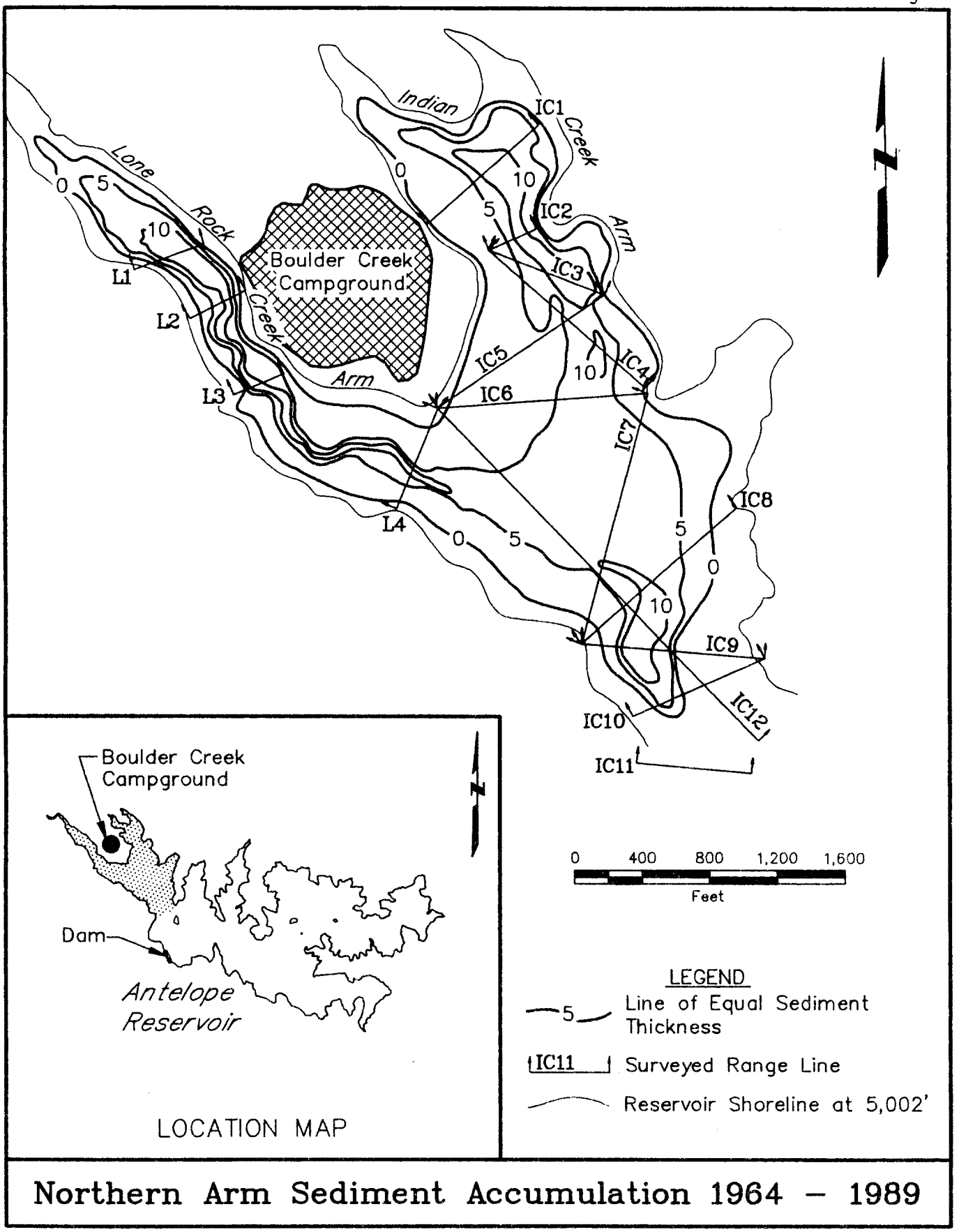
The annual sediment production from a watershed depends on climate, soil type, land use, topography, and other factors that affect runoff characteristics. In order to predict the rate of sediment yield to the reservoir, the trap efficiency and density of the sediment are also needed (Linsley et. al., 1982). Without those factors, the sediment rate is only a gross approximation averaged over the infilling period. The following sections discuss our estimate of watershed sediment yield rates above Antelope Reservoir based on this survey.

Volume Calculations

Figure 13 is an isopach map showing the thickness and extent of sediment in the northern arm of the reservoir. It was constructed by measuring the 1964-1989 change in depth along each range line then contouring the 0, 5, and 10 foot isopachs (lines of equal sediment thickness).

Table 1 shows the numbers that were used to calculate the sediment volumes for the Indian Creek and Lone Rock Creek delta deposits. The columns show the changes in cross-sectional area between 1964 and 1989 for each of the surveyed range lines, the length of section, the angle that the section crosses the reservoir axis, and the volume of sediment in that length of channel.

Figure 13



Northern Arm Sediment Accumulation 1964 – 1989

Table 1-Sediment Volume Calculations, Northern arm

Cross-section	1964-89 Area Change (sq ft)	Length (ft)	Angle (degrees)	Volume (yd^3)
INDIAN CREEK				
IC-1	4970	675	73	119,000
IC-2	2640	410	82	39,600
IC-3	6040	315	30	35,200
IC-4	1180	1695	85	73,700
IC-5	3520	335	73	41,800
IC-6	3710	840	78	113,000
IC-7	5950	260	45	40,400
IC-8	2960	390	74	41,100
IC-9	2340	350	84	30,000
IC-10	1260	408	85	18,900
LONE ROCK CREEK				
L1	2520	900	49	63,300
L2	1440	450	88	24,100
L3	2050	740	90	56,300
L4	1180	1695	85	73,700
			TOTAL (est)=	770,000

The sediment volumes in the Indian Creek and Lone Rock deltas are defined by ranges IC1 through IC10 and L1 thru L4, respectively. The total accumulated sediment in the northern arm of the reservoir is probably accurate to within +/- 20,000 cubic yards (5 percent of the total deposit).

Table 2 (next page) shows the numbers used to calculate the sediment volume in the southern arm of the reservoir. The volume was found using the same method as in the northern arm. The cross-sectional areas were estimated using ranges A1 through A4. The pattern of sediment accumulation was examined in stereo-paired photos from October, 1976 photos.

Table 2-Sediment Volume Calculations, Southern arm

Cross-section	1964-89 Area Change (sq ft)	Length (ft)	Angle (degrees)	Volume (yd^3)
ANTELOPE CREEK				
A1	600	800	62	15,700
A2	300	1000	68	10,300
A3	100	600	78	2,200
A4	200	900	74	6,400
Remaining S. Arm				
A6-A7	150	2000	90	11,100
A8-A10	50	4000	90	7,400
A11-A12	50	2000	90	3,700
			TOTAL (est)=	56,800

The accumulated sediment in the southern arm of the reservoir is probably accurate to within +/- 10,000 cubic yards (35% of the total deposit).

The total volume of reservoir sediment calculated from these data is 830,000 cubic yards (510 acre-feet). This represents a two percent decrease in the 22,500 acre-feet original storage capacity of the reservoir since 1964. The sediment does not present an operational problem to the dam's outlet structure. Maintenance divers have confirmed that the intake structure is clean (pers. comm., Conrad Lahr).

Sediment Production Estimates

The U. S. Department of Agriculture, River Basin Planning Staff, found that the average dry weight of reservoir sediments in Morris, Walker, and Pillsbury Reservoirs is 67 lbs/cubic feet, (SCS, 1970). This is probably representative of the finer-grained sediments in the Coast Range reservoirs of northern California. Linsley, et. al.,(1982) suggests that the density for coarse-grained reservoir sediments ranges from 85 to 100 lbs/cubic feet depending on submergence time and other factors.

Trenching in the Lone Rock and Indian Creek deltas shows that the sediment there consists of 3 to 4 inch-thick lenses of alternating organic-rich, silty sand and coarser, granitic sand (Photo 5). Limited reservoir bottom sampling suggests that the reservoir sediment is predominantly coarse sand. From these data, the weight of the sediment is assumed to be 90 lbs/cubic feet. Using this value, the total weight of the deposited material is 1.0 million tons and the indicated rate of sedimentation is 40,000 tons/year over the 1964-89, 25 year period. This would represent a uniform loss of 560 tons/sq mile/year if the basin was eroding uniformly over the entire 71 square mile watershed above Antelope Reservoir, and if all the sediment was deposited in the reservoir.

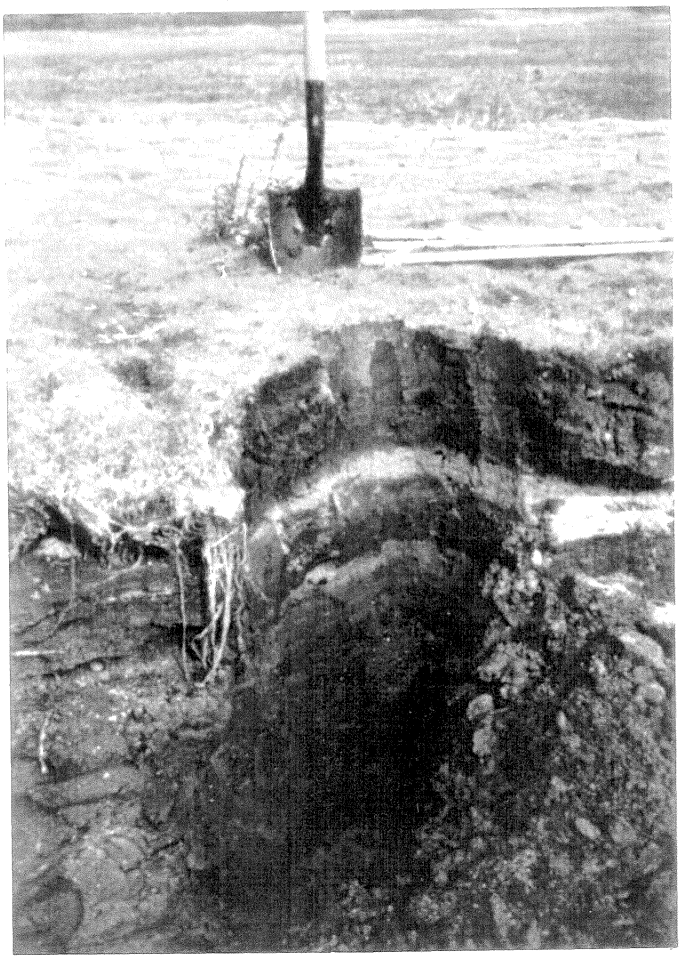


Photo 5: Sediment profile on Lone Rock Creek stream bank showing alternating lenses of fine and coarse sediment.

This survey suggests that sediment production is not uniform over the entire watershed. The estimated sediment production rates in three sub-watersheds above Antelope Reservoir are shown in Table 2. The drainage area boundary is defined by the topographic divide between sub-watersheds. These areas were planimetered from a 15-minute USGS quadrangle.

Table 3-Watershed Sediment Yield Rates

Study Area	Annual Sediment (Tons/year)	Drainage Area (sq miles)	Sediment Yield (Tons/sq mi/year)
Indian Creek (incl. Boulder Cr)	26,860	39	690
Lone Rock Creek	10,600	12	880
Antelope Creek	1,700	9.5	180
Remaining S. Arm	1,100	10.3	110
TOTAL	40,260	70.8	Average = 570

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APPENDIX A: Methodology, control points and range end points for reservoir survey.

State of California

The Resources Agency

Memorandum

Date : January 29, 1990

To : Jack McMillan

From : Julie Culp
Department of Water Resources

Subject : Antelope Reservoir Survey

The surveying of Antelope Reservoir for sedimentation was done from 8-28-89 to 9-29-89. Shawn Pike, Jack McMillan and I were responsible for setting control points, cross section end points and surveying cross sections. This memo describes our procedures.

We began our survey at the dam spillway bridge at DWR benchmark AD-1. We called this benchmark point 1 and assigned it temporary coordinates of 10000N, 10000E. After taking a north bearing and zeroing the instrument, we shot to point 2 to determine its coordinates. Point 2 was the backsight. The instrument we used was a Lietz Set 3. We kept our horizontal traverse and level notes in a field book and our topographic data in the SDR2 data collector.

Points 1-11, 20, 21, 31 & 41 are control points. Points 100 - 115 are cross section end points. Two closed traverses were run. The angles to all the control points were doubled to check for error. A maximum of 20 seconds difference was allowed between the two angle readings. In the office, the data was entered into the computer to determine the closure error using the software package "COGOPC". Both traverses closed with a ratio of less than 1/50,000. The coordinates of all these points were changed into California Coordinates based upon a topographic map of the area. The accuracy of these coordinates is estimated to be within 25 feet.

Elevation for control points was determined from the reservoir water surface elevation. Reservoir elevations were read off the staff gage at the spillway once on Wednesday morning and one on Thursday morning. Since the two readings had changed, a constant drop of elevation equal to the change in elevation from 4997.81 feet to 4997.76 feet per time was assumed. Times were noted in the field book when elevations were being run. Level loops were run from the reservoir to the control points.

Elevations for cross section end points were determined from the control points. Instrument height over the control point and rod height at the cross section end points were recorded. The instrument displays the vertical height difference between the instrument and the prism on the road. The equation for determining elevation is:

SURNAME	Julie Culp 1-31-90			

DWR 155 (Rev. 8/83)

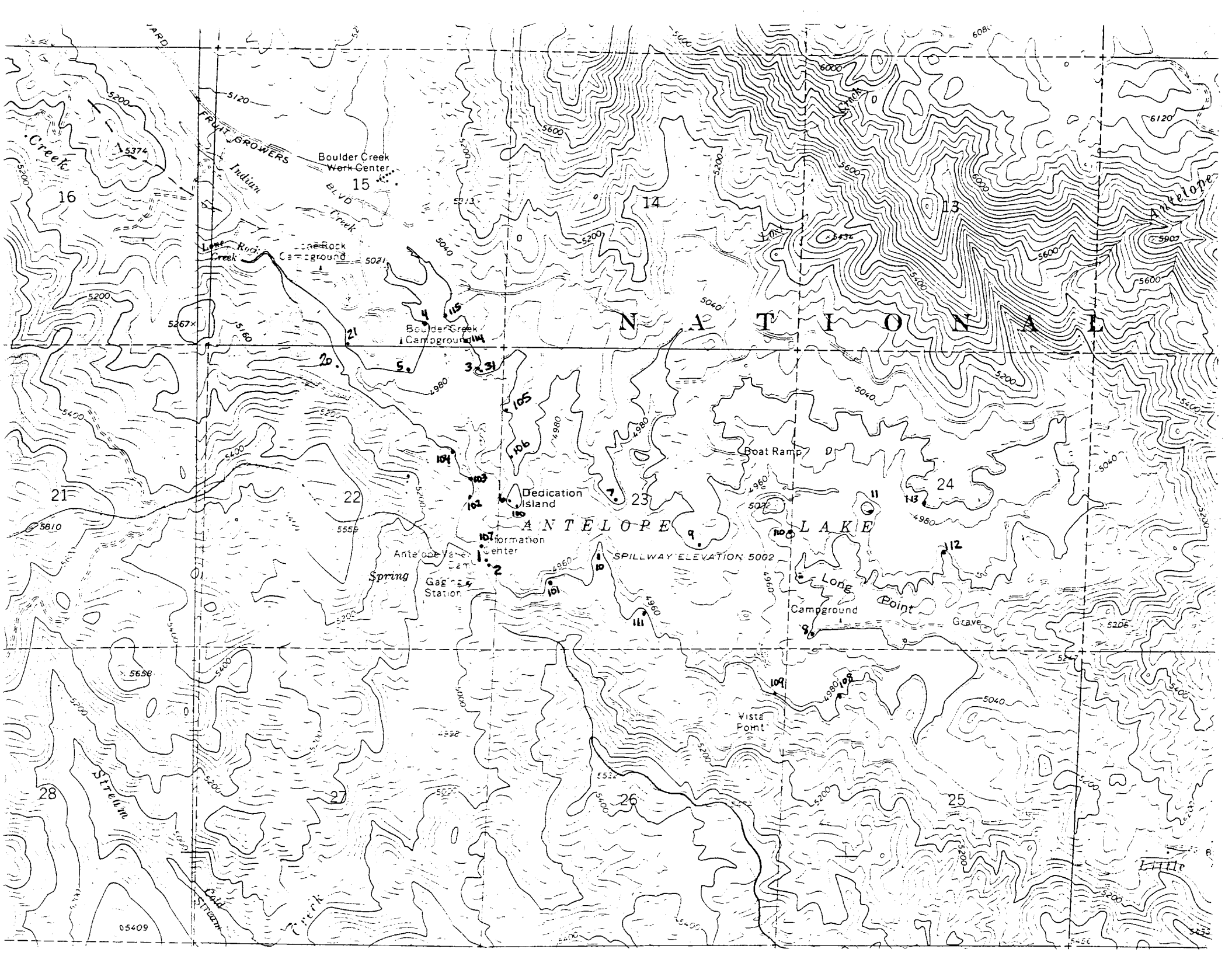
Elev(xsec end pt) = Elev(control pt) +intru.ht. + vert. ht. - rod ht

One cross section was run on dry land north of point 4 on Indian Creek. Two cross sections were run on dry land north of point 21 on Lone Rock Creek. Elevations and distances were determined the same way as the cross section end points.

Point Descriptions

Point	
1	DWR brass cap AD-1 on NE corner Antelope spillway bridge. Elevation 5026.20.
2	Nail in concrete at SE most corner of bridge.
3	Chiseled X in large rock at north end of large group of rocks on a point of the lake.
4	Pipe in concrete about 25 ft S/o waters edge near rock to the east of Boulder Creek Campground.
5	Pipe in ground S/o Boulder Creek Campground near car top boat launch.
6	Rebar in ground on west side of Dedication Island about 10 ft E/o large rock.
7	Rebar in ground near large tree.
8	Rebar in ground near tree near campground on Long Point.
9	Pipe or rebar in ground.
10	Rebar in ground on point of lake on north side of large rocks.
11	Rebar in ground on SE side of island.
20	Rebar in ground.
21	Rebar in ground.
31	Rebar in ground at S end of a rock about 30 ft SE of pt 3.
41	Rebar in ground.
100	Pipe in ground on south side of Dedication Island, near boulder pile.
101	Pipe in ground.
102	Pipe in ground at base of a small tree 10 ft W/o fallen log.
103	Pipe in ground
104	Pipe in ground, at east base of large boulder rock outcrop.
105	Pipe in ground, near prominent snag.
106	Pipe in ground. 10 ft W/o large lone sugar pine tree.
107	Rebar in ground near boulders 50' N/o Kiosk.
108	Rebar in ground.
109	Rebar in ground.
110	Pipe in ground.
111	Rebar in ground.
112	Rebar in ground.
113	Rebar in ground.
114	Pipe in ground.
115	Pipe in ground.

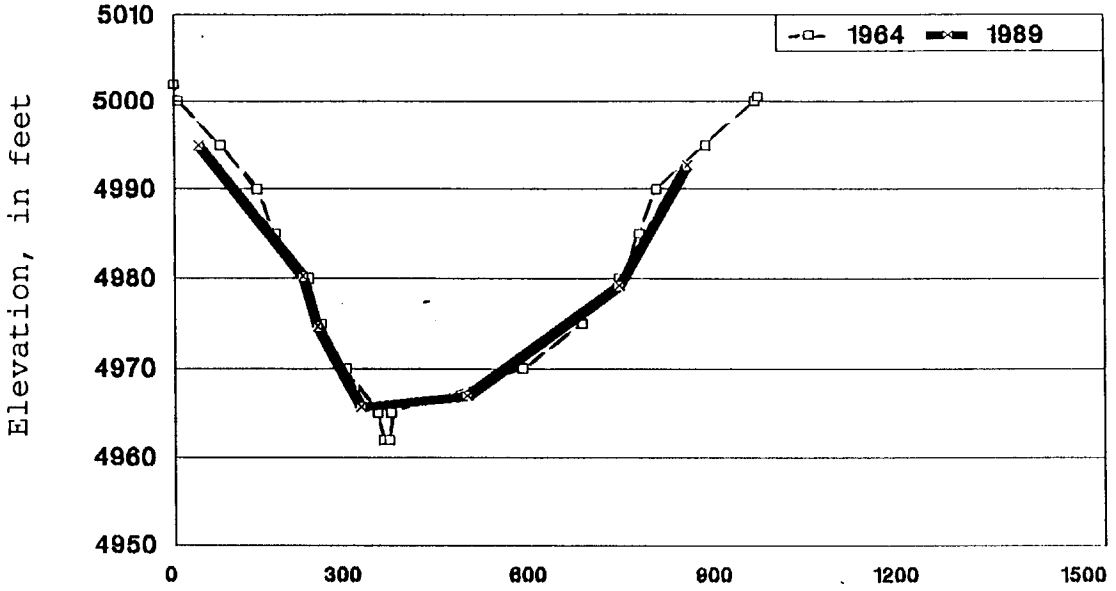
Note: All points others than 1, 2, and 3 are pipe or rebar. Some error may have occurred in recording the type for each point.


FRUIT GROWERS
Boulder Creek Work Center
BLVD
Indian Creek
Lone Rock Creek
Lone Rock Campground
Boulder Creek Campground
NATIONAL
Boat Ramp
Dedication Island
ANTELOPE LAKE
SPILLWAY ELEVATION 5002
Information Center
Antelope Valley Spring
Gaging Station
Long Point Campground
Grave
Wiste Point
Stream
Cold Stream
Creek
Antelope
Little
05409

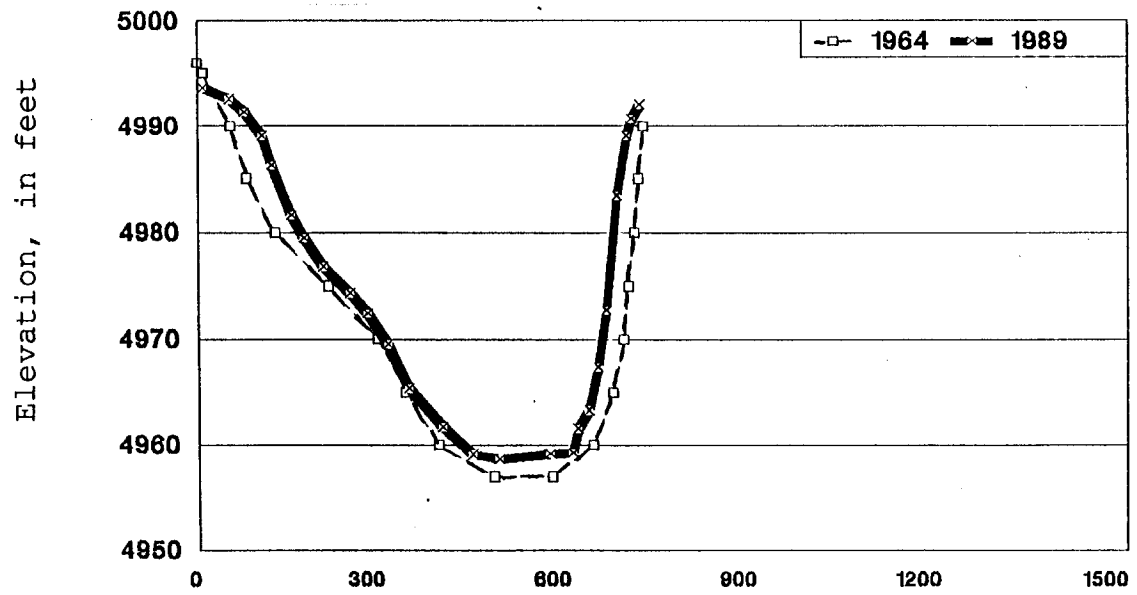
APPENDIX B: Southern arm reservoir ranges
A3 through A12.

Figure B1

A3-LINE
West----->East

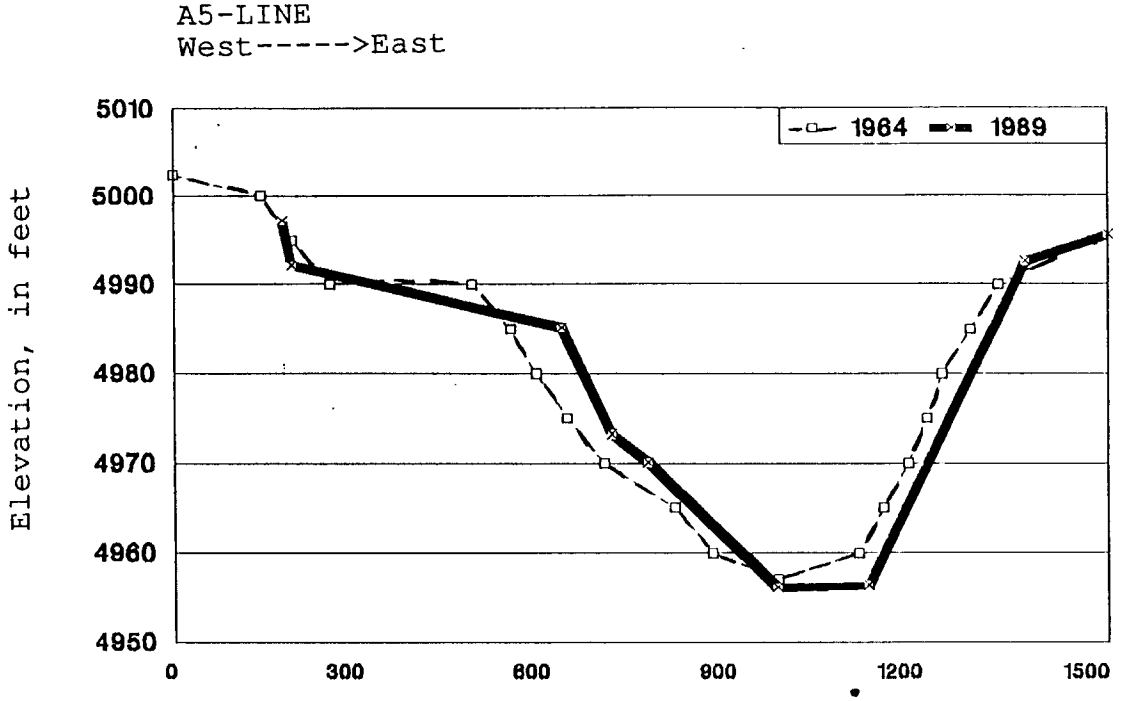


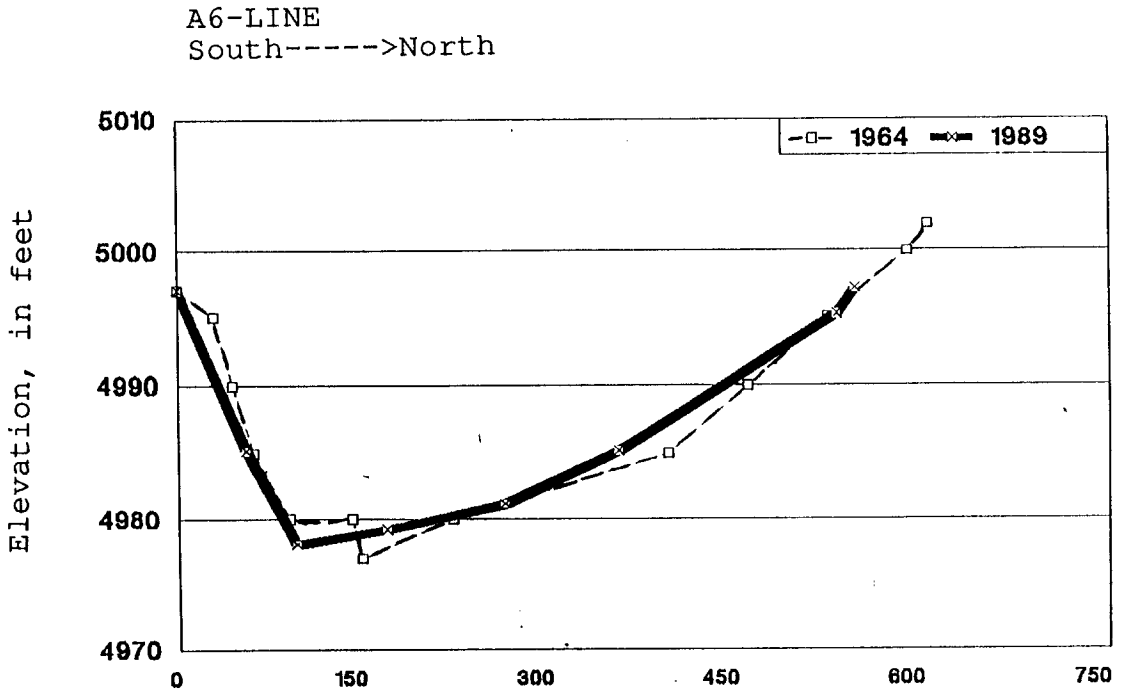
A4-LINE
North----->South



Distance along range lines, in feet

Figure B2

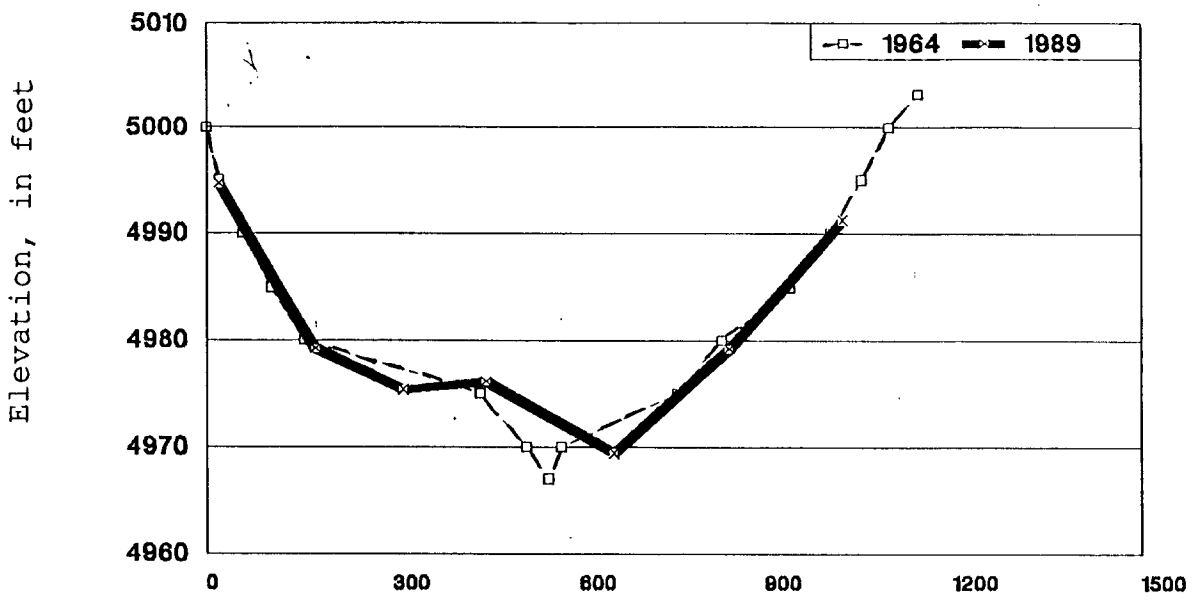




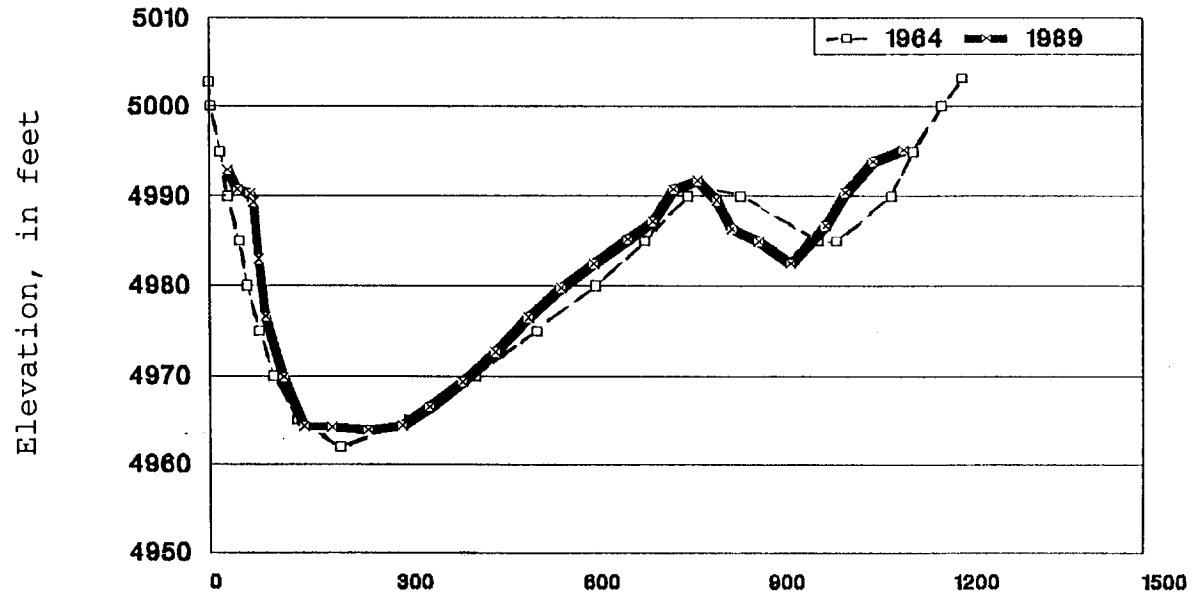
Distance along range lines, in feet

Figure B3

A7-LINE
South----->North



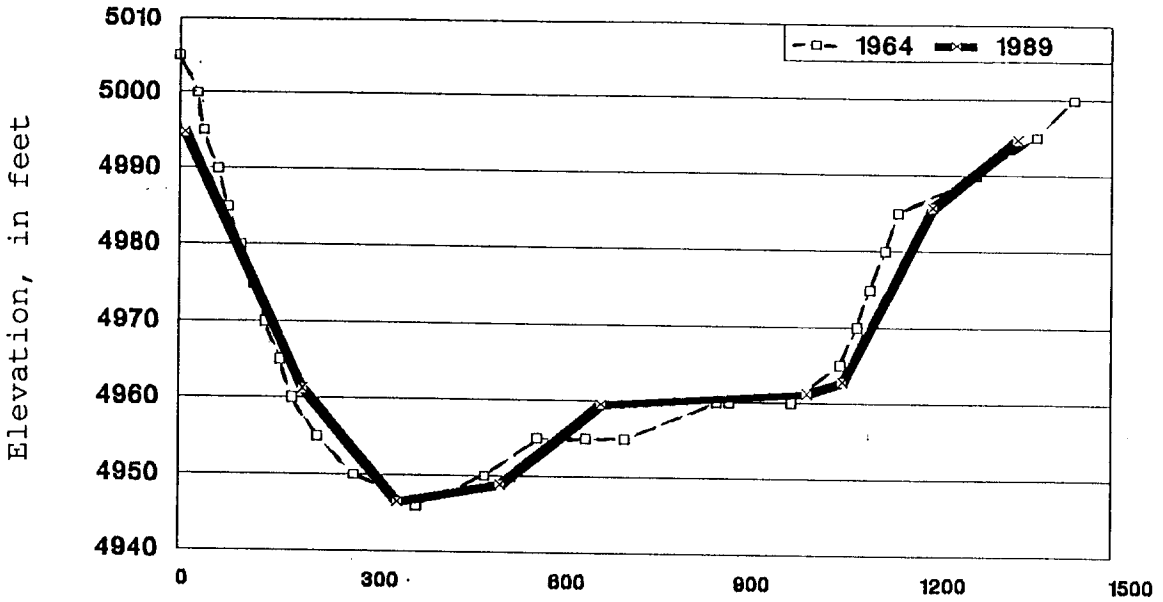
A8-LINE
South----->North



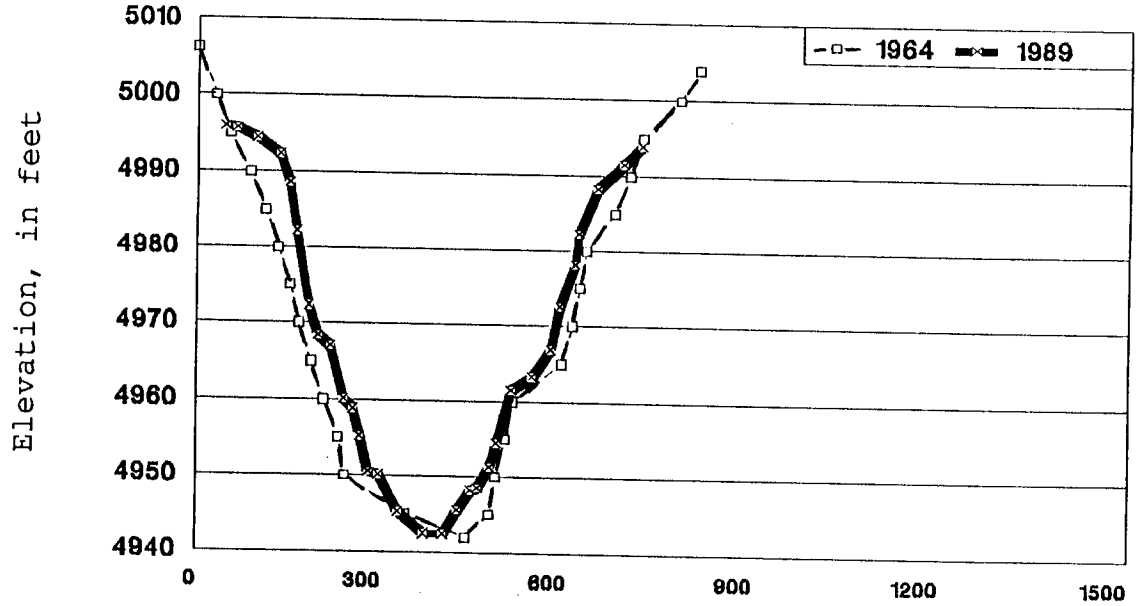
Distance along range lines, in feet

Figure B4

A9-LINE
South----->North



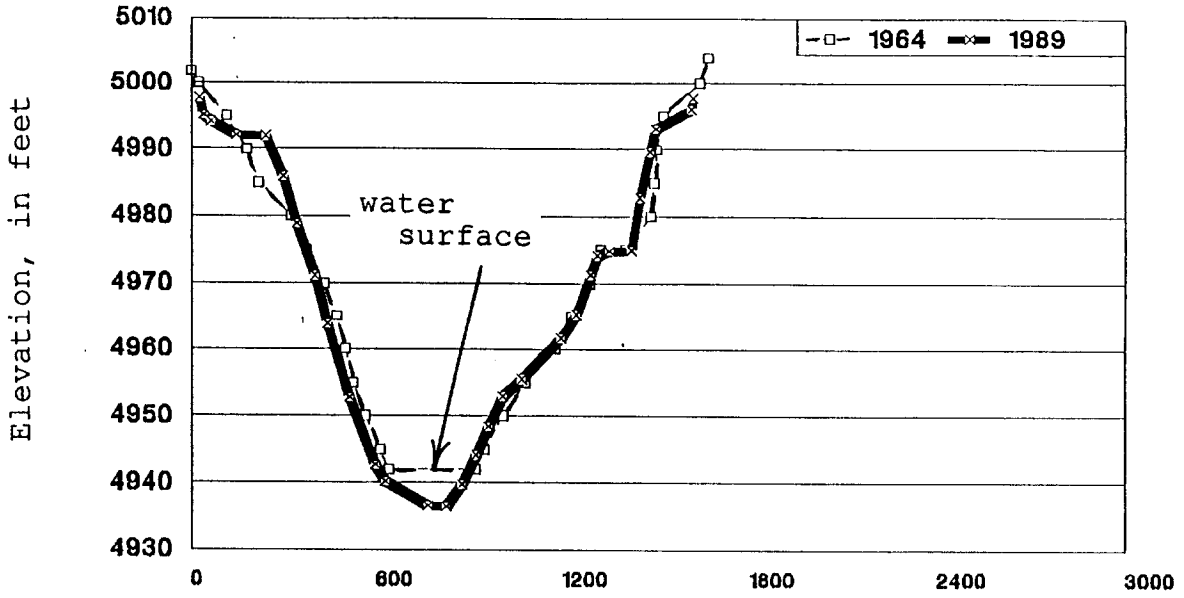
A10-LINE
South----->North



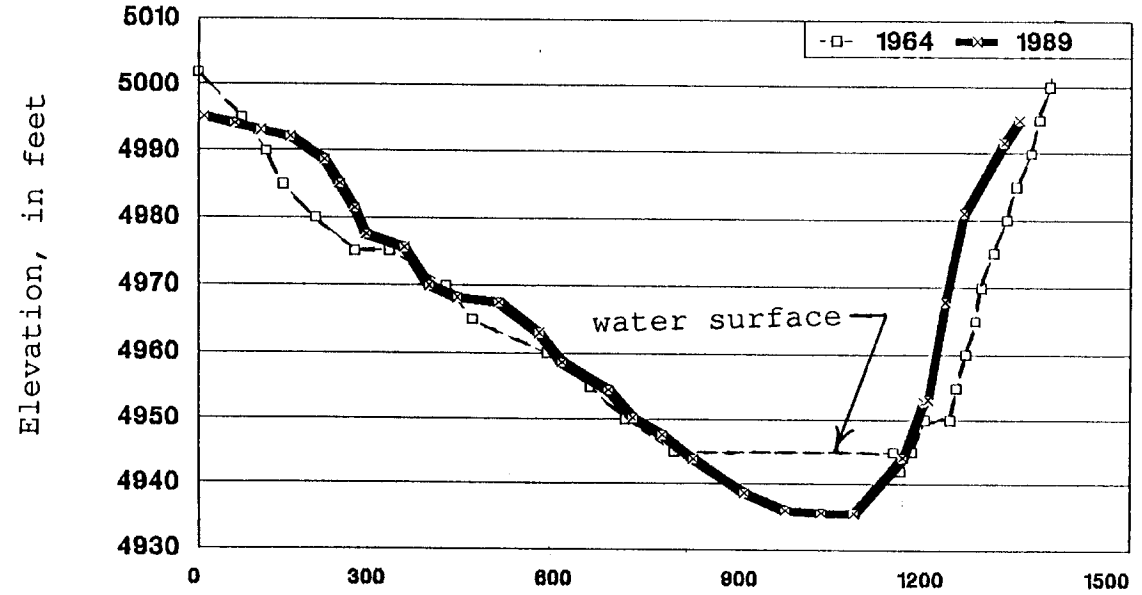
Distance along range lines, in feet

Figure B5

A11-LINE
Northwest----->Southeast



A12-LINE
North----->South



Distance along range lines, in feet